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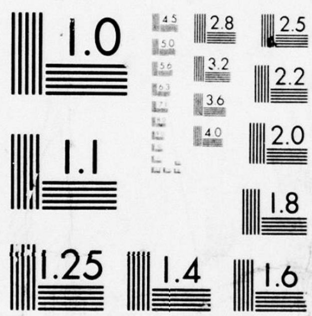

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Wright-Patterson Air Force Base, Ohio

AN ANALYSIS OF INFORMATION SOURCES FOR THE ESTIMATION OF LIFE CYCLE OPERATING AND MAINTENANCE COSTS OF TURBINE ENGINES

Michael D. Baker, Captain, USAF
Bruce B. Johnston, First Lieutenant, USAF

SLSR 11-77A

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This study is an attempt to locate, analyze and evaluate data bases which contain operation and support (O&S) cost data for aircraft engines. The search for these data bases was primarily conducted at Headquarters, Air Force Logistics Command. The study focused upon the Increase Reliability of Systems (IROS) data base, the HO36B DOD Cost and Production Report, the AFM 400-1 actuarial data system, the cost and planning factors in AFR 173-10, aerospace ground equipment data located in the Tables of Allowance, and Component Improvement Program data located at the Deputy for Propulsion, Aeronautical Systems Division. The study of these data bases led to the conclusion that data bases in the Air Force are not well designed for cost data collection and that many data bases are necessary to obtain the total operation and support cost of an aircraft engine.

SLSR 11-77A

AN ANALYSIS OF INFORMATIONS SOURCES FOR THE ESTIMATION OF LIFE CYCLE OPERATING AND MAINTENANCE COSTS OF TURBINE ENGINES

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for

Degree of Master of Science in Logistics Management

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June 1977

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and

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has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT
(Captain Michael D. Baker)

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT (PROCUREMENT MAJOR)
(First Lieutenant Bruce B. Johnston)

DATE: 15 June 1977

Martin D. Martin

COMMITTEE CHAIRMAN

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CHAPTER I

INTRODUCTION

Statement of Problem

Operation and support (O&S) costs comprise a significant portion of the life cycle costs (LCC) of a weapon system where life cycle costs are defined as:

> The sum total of direct, indirect, recurring, non-recurring and other related costs incurred, or estimated to be incurred in the design, development, production, operation, maintenance and support of a major system over its anticipated useful life span [10:3].

The release of Office of Management and Budget Circular A-109 in April 1976 requires Federal agencies in the Executive branch which design, develop and acquire major systems to estimate the O&S costs of these systems during their initial design (10:1-2).

While the system's total costs can never be predicted with complete accuracy, awareness of life cycle costs concepts and application of the associated techniques allow for better planning and decision making (6:3).

One agency which develops major systems is the Aero Propulsion Laboratory (For a fuller description of the Aero Propulsion Laboratory, see Appendix B), located at Wright-Patterson Air Force Base, Ohio. Historically, personnel at the Aero Propulsion Laboratory have not

generally concerned themselves with the future O&S costs of the aircraft engines which they design. They now have a new and urgent need for data which can be used to estimate the O&S costs of aircraft engines (33). This research effort will attempt to identify sources for this data.

Definitions

To insure a common understanding of key concepts, the following terms are defined as they will be used in this study.

A. Data and Information - Data are unevaluated facts, concrete in nature, that are readily quantified (25:27). Information, on the other hand, refers to material which has been analyzed and evaluated and is judgmental and conceptual in character. Information is derived from data; it is the result of data interpretation (25:27-35).

B. Data Base - The term data base refers to the information file in a data base system. The data base system is the entire hierarchy of elements, files and computer applications programs which results in efficient management of information. In its most basic form, a data base consists of a number of data elements, each of which is a unit of data that is complete in itself. A part number, for example, is a typical data element. These elements are organized into logically related groups.

called data structures. A common data structure is a part number, its description, its supplier code, and its inventory status.

Information files, or data files, are composed of a large number of data structures of the same type. The data files in a data base system are organized in a fashion that permits their use in several applications (25:27-35).

C. Operation and Support Cost - The total cost associated with operating and supporting a system throughout its entire life cycle. It does not include acquisition and production costs; it does include the costs of system disposal (45:11).

D. Life Cycle Costing - "The consideration of life cycle cost or segments thereof, in various decisions associated with acquiring an item of equipment or a defense system [45:9]." The important distinction between life cycle cost and life cycle costing is that one is an actual cost, the other is a management tool for evaluation purposes (19:35-38).

E. Management Information System -

> The combination of human and computer-based resources which results in the collection, storage, retrieval, communication, and use of data for the purpose of efficient management of operations. . . [7:1-16].

The important term in this definition is computer-based. The information systems that this study will search will

be computer-based.

The following definitions were extracted from Technical Order 00-25-128, Procedures for Determining Aircraft Engine (Propulsion Unit) Failure Rates, Actuarial Engine Life, and Forecasting Monthly Engine Changes by the Actuarial Method.

F. Actuarial Science -

A mathematical science, the principles of which are applied to human statistics to perform studies in life contingencies, calculate human life expectancy and mortality rates, and compute insurance risks and premiums [49:1-25].

G. Air Force Actuarial Program -

The program consisting of the development and use of actuarial mathematics and the theory of probability for determination of failure rates and life expectancies for Air Force materiel [49:1-25].

H. Air Force Actuarial Method for Aircraft Engines -

A method for applying the principles and techniques of actuarial science to the field of Air Force engine management [49:1-25].

I. Engine Life

Engine life is the number of flying hours which new or newly overhauled engines (age zero hours) attain on an average before being removed for major overhaul for usage reasons or maximum allowable operating time. Several terms have been used to represent engine life. It must be kept in mind that the general purpose of all the terms is the same, i.e., each is an attempt to express the average number of flying hours in the life of the engine [49:1-25].

J. Actuarial Engine Life (AEL) -

This factor is the expected number of flying hours

per depot maintenance failure which will occur when the engines are distributed throughout their life span. It is an actuarial factor based on a set of depot maintenance failure rates which vary by age interval from age zero to maximum time. Briefly, it is found by hypothetically flying a group of new engines until ALL have failed, and then dividing the total hours flown by the number of engines (or failures) [49:1-25].

Background of the Problem

The weapon system life cycle. The acquisition and support of jet engines represent a very large investment to the Air Force. The 1976 Procurement Management Review Team reported that the Air Force currently owns and maintains almost 38,000 gas turbine engines which represent an investment of approximately $10 billion, with an additional yearly expense of $500 million to maintain operational capabilities (9:1). The life cycle of a turbine engine is similar to any major weapon system and is composed of five distinct phases: conceptual, validation, full scale development, production/deployment and the operational/support phase (Disposition or salvage is sometimes considered a sixth phase).

The conceptual phase is the first phase of weapon system's life cycle. The Air Force analyzes a particular Required Operating Capability for a proposed system and attempts to determine the need, technological capabilities, economic base, and initial cost estimates of the new system (9:34). Primary considerations are substantiating

need, verifying technical capabilities and evaluating alternatives (9:34).

The validation phase is the next phase and the primary activity during this period is validation of the design for future production (11:8). Program characteristics such as performance, cost and schedule are developed. Baseline support requirements, initial prototypes and initial test and evaluation of the basic design are conducted during this phase (11:8). The major purpose of the validation phase is "to select the system and contractors for the development effort (9:46)."

After the design is validated, full scale development begins. A specified number of prototypes are built, tested and evaluated. Emphasis during the full scale development phase is on reducing the technical risks and producing a system which will function in the desired manner (22:2-6). Additional research and development for system improvement is conducted and the decision to proceed with procurement of the best prototype is made (11:9).

Once the decision to proceed with production is made, the system enters the production/deployment phase. During this phase, fabrication of the system takes place and all training and support needs are obtained so that the newly produced system can be operationally deployed. Additional research and development (R&D) for the

necessary component improvement is carried out. Initial spares are produced and any special equipment is procured (11:9).

The production phase overlaps with the operational/support phase, but the breakpoint between the two phases is usually considered to be the Program Management Responsibility Transfer (9:140). The operating and support phase is usually the longest phase, generally lasting over 15 years for engines (11:9). The system matures, and when it has served its purpose, is disposed of or modified to perform another mission function (11:9).

Figure 1 is a graphical representation of these phases in a system's life cycle and also includes a listing of the functional areas which have primary responsibility for the system during each phase.

In the Air Force, responsibility for a weapon system is organizationally shared by the Air Force Systems Command (AFSC) and the Air Force Logistics Command (AFLC) (38). During the early phases of the weapon system's life cycle, AFSC has the major engine responsibility. As the system progresses further in its cycle, AFLC has increased responsibilities until during the operating and support phase, AFLC almost has total responsibility (38). This sharing of responsibility is graphically depicted in Figure 2.

Figure 1

Activities During the Weapon System's Life Cycle (29:63)

Phase	Concept Formulation	Validation & Ratification	Full Scale Development	Production: Initial	Production: Full Scale	Deployment & Maturation	Steady State Operations	Obsolete/ Salvage/ Replacement
Defense Systems Acquisition Review Council (DSARC)		DSARC I	DSARC II	DSARC III				
	1-2 yr	1-2 yr	4-8 yr	4-12 yr		4-8 yr	5-15 yr	3-5 yr
Responsible Parties								
Primary *	Planner *	Developer *	Contractor *	Developer *	Contractor *	User *	User *	User *
Secondary o	User o	Contractor o	Developer o	Contractor o	Developer o	Developer o	Supporter o	Planner o
	Developer o	Planner o	User o	User o	User o	Contractor o	Contractor o	Supporter o
	Contractor o	User o	Planner o	Supporter o	Supporter o	Supporter o	Trainer o	Developer o
	Supporter o	Supporter o	Supporter o	Trainer o	Trainer o	Trainer o	Planner o	Contractor o
	Trainer o	Trainer o	Trainer o	Planner o	Planner o	Planner o	Developer o	Trainer o

Figure 2

Organizational Responsibility for a Weapon System During Its Life Cycle (38)

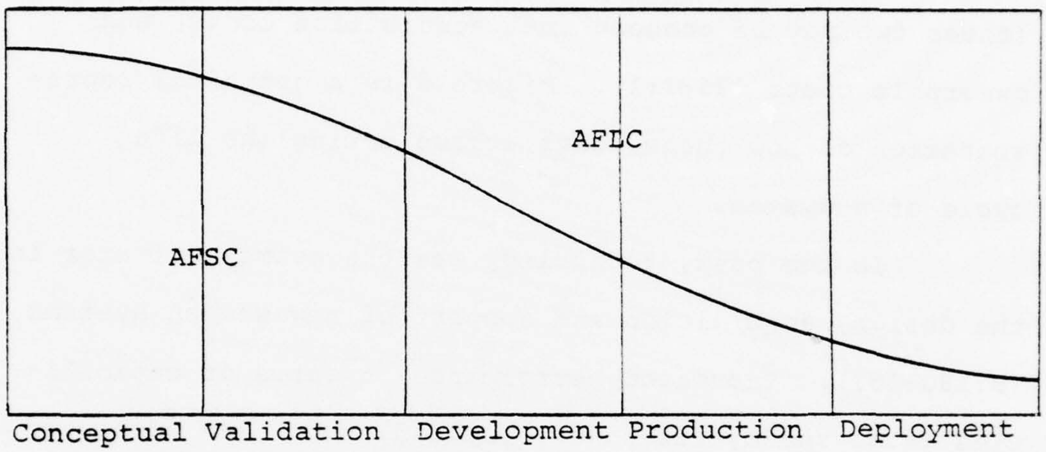
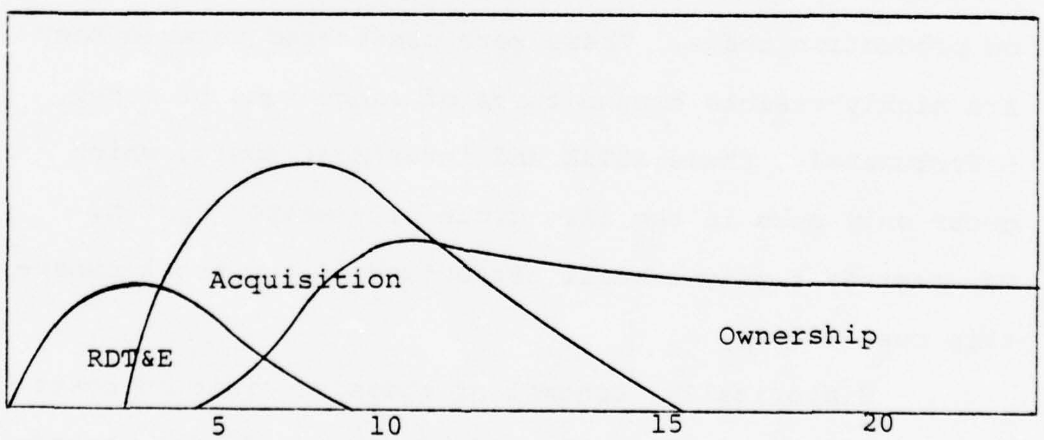


Figure 3

Accrual of Costs During a System's Life Cycle (38)



Weapon system costs. Any weapon system has a total cost which is accumulated during the entire life cycle of the system. To ease conceptualization of this total cost, it is helpful to break this cost out into three basic categories: development costs (RDT&E), production costs (these two may be grouped into acquisition costs) and ownership costs (26:1:1). Figure 3 is a graphical representation of how these costs accrue during the life cycle of a system.

In the past, technology was the prime motivator in the design, acquisition and support of new weapon systems (9:180-181). Increased performance in terms of capabilities (e.g. speed, firepower, payload, etc.) was advocated to meet new or growing threats, while cost was relegated secondary consideration (7:180-181). If cost was considered at all, emphasis was placed on the research, development, testing and evaluation (RDT&E) costs and on production costs. These were considered because they are highly visible expenditures of large sums of money. Unfortunately, these RDT&E and investment costs, which occur only once in the life cycle of a weapon system, may represent only a small percentage of the total ownership cost (32:2).

Historically, control of these acquisition costs has been the measure of the effectiveness of cost management. How closely the program manager followed his budget

and avoided cost overruns has been the important question (19:8). This condition has provided consistent motivation for both Government and industry planners to propose systems which are advantageous from the standpoint of military effectiveness and manufacturing cost, without devoting adequate attention to problems and costs of operation and support (22:3).

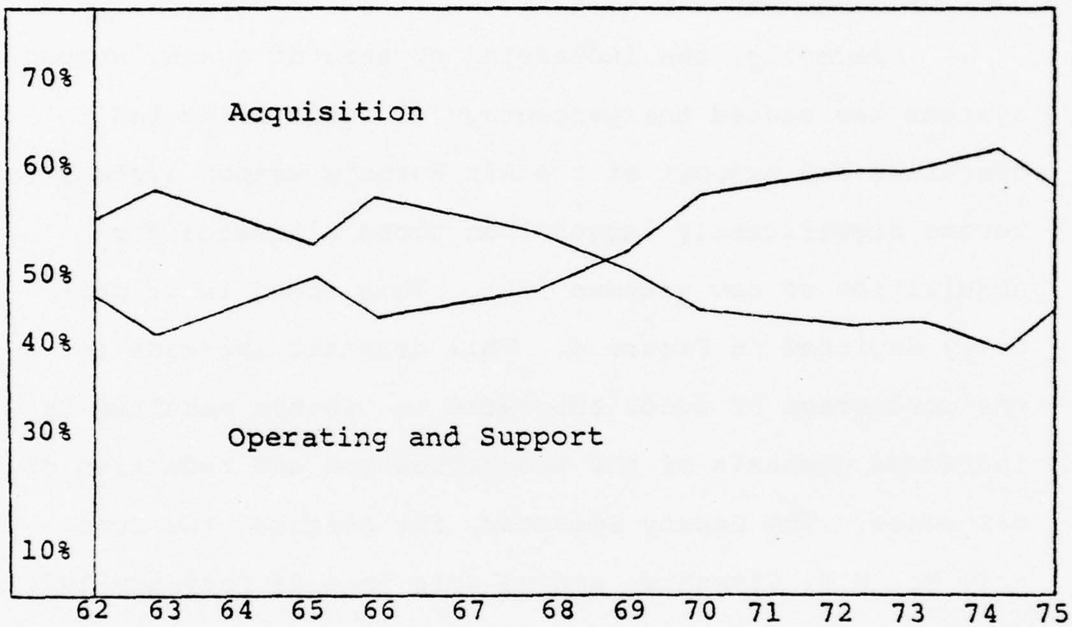
Recently, the increasing expense of owning weapon systems has caused the percentage of funds allocated to operating and support of the Air Force's weapon systems to become significantly larger than those allocated for acquisition of new weapons (35). This trend is graphically depicted in Figure 4. This dramatic increase in the percentage of funds allocated to O&S has resulted in increased emphasis of the identification and reduction of O&S costs. The Deputy Secretary for Defense, the Honorable Mr. W.P. Clements, stated this in a 28 February 1976 memorandum to the Secretaries of the Military Departments:

> We must have the dual objective of reducing the fraction of the outyear DOD budget allocated to weapon O&S costs while at the same time maintaining operational readiness. . . . While I am confident that we can achieve the ability to identify and track these costs, I am equally concerned that insufficient attention is being paid to controlling eventual system O&S costs during conceptual, validation and full-scale development phases of new systems. My objective is to achieve an overall reduction in the fraction of each Service's outyear budget allocated to O&S cost in the outyears by focusing now on reducing the O&S cost of the new systems we are developing [8:11].

One technique which can be used to identify life cycle costs, including O&S costs, is life cycle costing.

Figure 4

Percentage of Air Force Funds Spent for Acquisition and Operation and Support of Weapons Systems (35)



Life cycle costing. Air Force Regulation 800-11, Life Cycle Costing defines life cycle cost as follows:

> The total cost of an item or system over its full life. It includes the cost of development, acquisition, ownership (operation, maintenance, support, etc.) and, where applicable, disposal [45:11].

By using life cycle costing during the acquisition phase, decision makers can place emphasis on all costs of

ownership, not just development and acquisition costs. Life cycle costing provides an excellent perspective of the total economic advantages and disadvantages of the various design and development options available to program managers (45:3).

Recently, the DOD has specified that life cycle costing will be used in the acquisition process (8:1). Many factors have contributed to this new policy; the dominant consideration is the need to emphasize the magnitude of O&S costs (19:82). The cost of operating and supporting a weapon system has been steadily increasing for many years (19:1). This increase can be directly attributed to personnel and material costs. While the total inventory of Air Force aircraft has decreased from 15,000 in 1960 to under 7,500 today, the ratio of personnel to aircraft has increased from 78 to 115. Personnel costs during this same period, 1960 to 1976, have increased from 40% to 50% of the total Air Force budget (40:78-81). The cost of raw materials such as titanium, copper, aluminum, etc., have increased substantially in the last decade, often as much as 200-300 percent (19:2).

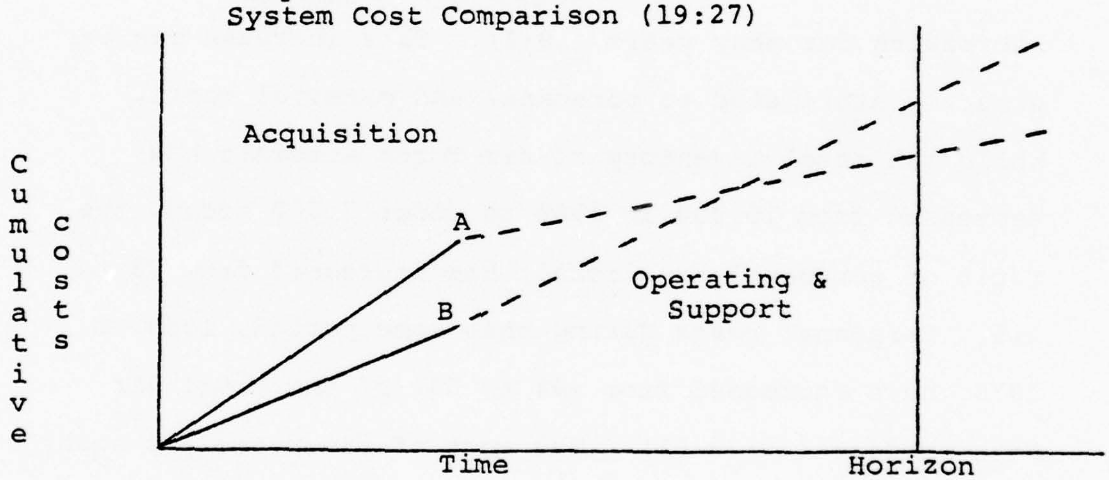
> The cost of operating and supporting defense systems over their useful life is generally greater than, and often several times greater than, the initial acquisition price [14:1].

The impact of O&S costs can be clearly seen in Figure 5. Two alternative system acquisitions are

graphically depicted in Figure 5. Both alternatives are assumed to be equally acceptable from a performance, effectiveness, and risk standpoint. Since the initial cost of B is less than the cost of A, it would be chosen if selection were based on per unit production cost. When O&S costs are included in a total system cost projection to a convenient time horizon, such as 10 years of operational use, alternative A actually proves to be the best choice (19:37).

Figure 5

Impact of O&S Costs on Total System Cost Comparison (19:27)



Not only is the capability of determining life cycle costs important, but the point in the life cycle at which life cycle costs can be estimated is equally important (9:98). This is true because most of the life cycle costs of a system are defined relatively early in the system's life cycle. Some studies show that by the

end of full scale development, 95% of the systems life cycle costs are defined by design decisions made up to that point (9:98). The impact of these decisions upon the definition of life cycle costs is graphically illustrated in Figure 6.

Up to this point, the importance of a weapon system's life cycle cost has been discussed. Life cycle cost considerations for engines are equally important. Throughout the developmental phase of an engine, there are many tradeoffs to be made in terms of time, quality, quantity, complexity and cost (26:5). For example, if we increase the quality of an engine (in terms of maintainability and reliability) the acquisition costs tend to increase (Figure 7), while the ownership costs tend to decrease (Figure 8). The solution to the problem is to design that amount of quality into the system which will result in the lowest total cost (Figure 9). Life cycle costing is a tool which the decision maker can use to help him make the proper tradeoffs early in a weapon system's life (26:1-4).

The evolution of life cycle costing in the DOD has been relatively slow. Although the DOD received its first exposure to life cycle costing in 1963, it was not until July 1965 that the DOD established a steering group to monitor an LCC test program (60:4). The results of the test program prompted DOD officials to state that LCC

was very appealing as a technique for cost control and that action would be taken to exploit the concept to its fullest extent. However, by May 1973 a General Accounting Office report indicated that life cycle costing was still not mandatory in the DOD (60:4). From 1973 to 1976 life cycle costing received increasing emphasis and study and the issuance of OMB Circular A-109 in April 1976 made the use of life cycle costing mandatory in the acquisition of major weapon systems (10:1-2).

Figure 6

Impact of Design Decisions on
Future Life Cycle Costs (9:98)

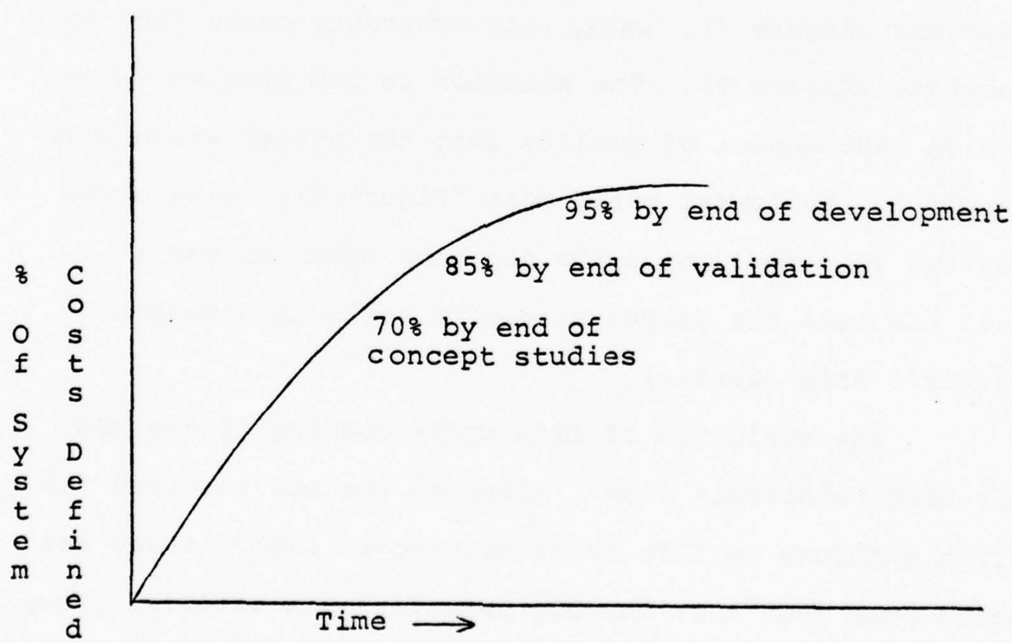


Figure 7

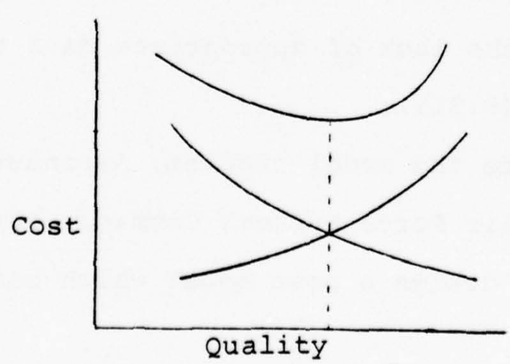
Acquisition Cost and Quality (29:26)

Figure 8

Ownership Cost and Quality (29:26)

Figure 9

Total Costs and Quality (29:26)



Impact of OMB Circular A-109. OMB Circular A-109, which applies to all departments of the Executive Branch of the Federal Government, sets forth major management objectives to be attained by organizations involved with systems acquisition. Two of these objectives directly impact the Aero Propulsion Laboratory:

1. That management will "ensure appropriate trade-offs [are made] among investment costs, ownership costs, schedules, and performance characteristics [10:4]."

2. That management maintains a capability to estimate life cycle costs during system design, concept evaluation and selection, full scale development, facility conversion, and production to ensure appropriate trade-offs among investment costs, ownership costs, schedules and performance (10:5).

Personnel at the Aero Propulsion Laboratory are capable of estimating the developmental and acquisition costs for jet engines; O&S cost estimation for these engines, however, presents a major problem (33). There are two causes for this problem, one is that very few cost models are applicable to O&S costs and/or jet engines and the second is the lack of appropriate data to use in an O&S cost model (9:311).

To alleviate the model problem, Aeronautical Systems Division, Air Force Systems Command, commissioned a working group to design a cost model which can compute

O&S costs for aircraft engines (9:312). This group, the Aircraft Engine Life Cycle Costs Methods Improvement Working Group, designed a model and published it in June 1976 (9:312). This model can be called the Working Group Model. Unfortunately, the model cannot be readily used by the Aero Propulsion Laboratory personnel because the data required to run the model are difficult to obtain (1).

At the present time, Aero Propulsion Laboratory personnel are attempting to fulfill the requirements in OMB Circular A-109 by using a cost model which is not designed for life cycle O&S costs and is not applicable to jet engines (1). The data for this model is obtained from AFR 173-10, <u>USAF Costs and Planning Factors</u>. The data contained in AFR 173-10 give cost breakdowns in terms of dollars per flying hour by aircraft type (50:20-25). The problem with these data is that they are not broken down into subsystems such as jet engines, and there are no data which specifically apply to O&S costs (1).

<u>Life cycle cost data</u>. The lack of adequate life cycle cost data in general and O&S cost data in particular is not a problem which is peculiar to the Aero Propulsion Laboratory. The following excerpt is from a November 1975 Rand report.

> How much does it cost to acquire and own a military engine? It would appear that still nobody knows! No study to date has clearly defined the cost elements and associated actual costs for any

ongoing engine program or the methodology for obtaining cost estimates in any detail for a new engine [30:19].

Later, in February 1976, the Procurement Management Review (PMR) team reported:

> The biggest deficiency in engine life cycle cost data is in the operational and support phase, i.e. after the engine enters the inventory. Although the PMR team was constantly told that "the data is out there" only one organization visited felt it was obtainable and offered to "dig" it out. . . . The ATC study shows that most of the data is there, but the formats are so varied and designed for other purposes, and the data is so piecemeal, that in its present form it is inadequate for determining engine life cycle costs [9:311-312].

The PMR team attributed the lack of cost data to the way in which functional managers are rated on their jobs. Management is mission and performance oriented, not cost oriented. For example, depot maintenance managers are rated on how well they meet their production schedules; field maintenance is rated on how well they generate engines to support sortie requirements; depot material management is rated primarily by Engine Not Operationally Ready Supply (ENORS) rates. Managers are concerned with their performance measures and if costs are considered it is from the standpoint of meeting local budgets with no regard to total life cycle costs. Because of this, the data systems are designed to accumulate cost data for organizational segments and engine management is fragmented (9:180-181). Therefore, existing data systems do not provide information which

can readily be used for cost estimation (21:28).

Turbine engines in the Air Force. Management of the Air Force turbine engine inventory is a large-scale operation, much larger than many DOD and Air Force personnel realize (20). This section will provide the reader with a basic background in the development and complexity of Air Force turbine engine management.

The development of the turbine engine can be characterized in one word, technology. The military's need for bigger, better and faster airplanes has caused the military to be the driving force in the development of turbine engines (9:26). The military has dominated turbine engine development because it has been willing to commit the large amount of resources necessary to bring new technology to fruition (9:26). The Air Force has developed more powerful and efficient turbine engines than were ever thought possible thirty-five years ago (9:11). Early turbine engines had problems with lubricating systems, compressor surging, bearings, heat dissipation, rotational speeds and high fuel consumption. Although great strides have been made, modern engine development is still concerned with these types of problems (9:12). Table 1 is a brief synopsis of aircraft turbine engine development since 1940.

The turbine engine has evolved into a highly complex and sophisticated piece of machinery. The

Table 1

Synopsis of Aircraft Turbine Engine Developments (29:80)

Early 1940s (WW II)	Late 1940s	Early 1950s (Korean War)	Late 1950s	Early 1960s	Late 1960s (Vietnam)	Early 1970s
Turbojet	Turbojet	Turbojet, Turboprop/ Turboshaft	Turbojet, Turboprop/ Turboshaft	Turbojet, Turboprop/ Turboshaft, Turbofan	Turbojet, Turboprop/ Turboshaft, Turbofan	Turbojet Turboprop/ Turboshaft, Turbofan
			Trends in engineering development			
Increased thrust	Augmentation	High-pressure ratio, variable stators	Cooled turbine	Supersonic turbofan	High-bypass turbofan (military and commercial)	High thrust/weight
Centrifugal to axial compressor	Two-position nozzle	Titanium begins to replace aluminum	Mach 3	Multi-design point mission	High-temperture turbine	High component performance
Single-design point mission	Stainless steel, aluminum, conventional steel	Sustained supersonic flight	Small lightweight engines	Superalloy materials	Cooling techniques	High-temperature materials
Limited use of high-temperature steels; primarily conventional steels	Higher pressure ration, dual rotor	Small helicopter engines	Commercial turbojet	Lightweight design	3-spool rotor	Cooling techniques
		Reliability/ durability	Subsonic turbofan	Component improvements	Compatibility/ integration	Composite materials
		Moderately higher turbine temperature	Titanium and superalloy material improvements	Commercial turbofan	Increasing sophistication of development	
			Transonic compressor		Commercial technology and requirements becoming as advanced as military	
			Companies			
General Electric	Allison	Allison	Allison	Allison	Allison	Allison
Westinghouse	Boeing	Boeing	Boeing	Boeing	Continental	Continental
	Curtiss Wright	Continental	Continental	Continental	Garrett	Garrett
	Fairchild	Curtiss Wright	Curtiss Wright	Curtiss Wright	General Electric	General Electric
	General Electric	Fairchild	Fairchild	Garrett	Lycoming	Lycoming
	Pratt & Whitney	General Electric	General Electric	General Electric	Pratt & Whitney	Pratt & Whitney
	Westinghouse	Lycoming	Lycoming	Lycoming		
		Pratt & Whitney	Pratt & Whitney	Pratt & Whitney		

following quote from the Procurement Management Review on Aircraft Gas Turbine Engine Acquisition and Logistics Support illustrates the complexity of the modern gas turbine engine:

> An engine consists of approximately 40,000 parts. All are interrelated and a change in one usually affects many others. These parts are exposed to a wide range of stresses, temperatures and wearing conditions. Some of the parts must operate over a 2500°F range of temperatures, with some of the engine hot section parts living in an environment above 2400°F. Pressure ratios achieved in modern engine compressors are in excess of 20:1. Rotational speeds approach supersonic conditions. The engine may encounter forces up to 40 g's. The external environment in which the engine operates is constantly changing. It must perform equally well from sea level to 60,000 feet or higher and in all types of weather conditions. The engine is either mounted on a wing or buried within the fuselage; in either case the temperature and pressure outside the engine varies and is unknown at times. The engine also experiences a wide range of vibration frequencies and amplitudes [9:31].

The Air Force has the largest and most diverse inventory of aircraft gas turbine engines of any organization in the free world (9:29). "These engines range from the small J-69's with 600 pounds of thrust to TF-39's with over 42,000 pounds of thrust [9:29]." The quantity and dollar value of all the engines the Air Force had in its inventory as of 31 December 1976 is displayed in Table 2. The total Air Force inventory of over 39,000 jet engines representing a total investment of almost 7 billion dollars is obviously large by any standard. To really appreciate the size of the Air Force turbine engine

Table 2

Installed and Spare Engines
U.S. Air Force (56)

(31 Dec 76)

ENGINE TYPE	% OF TOTAL	QUANTITY	DOLLARS IN MILLIONS
JETS			
INSTALLS	76.6	30,112	5,271
SPARES	23.4	9,221	1,645
TOTAL	100.0	39,333	6,916
RECIPS			
INSTALLS	61.1	1,620	43
SPARES	38.9	2,546	114
TOTAL	100.0	4,166	157
MISSILES			
INSTALLS	58.8	268	96
SPARES	41.2	188	24
TOTAL	100.0	456	120
APUs			
INSTALLS	68.8	2,079	38
SPARES	31.2	941	17
TOTAL	100.0	3,020	55
GTUs			
INSTALLS	79.9	5,002	71
SPARES	20.1	1,262	19
TOTAL	100.0	6,264	90
TOTAL			
INSTALLS	73.4	39,081	5,520
SPARES	26.6	14,159	1,820
GRAND TOTAL	100.0	53,240	7,340

inventory, a summary of the commercial jet engine inventory in the United States is provided in Table 3. It is interesting to note that the largest American airline, United, manages 1,365 engines while the Air Force manages 39,000.

> The total number of engines owned by all airlines and the subtotals for the three largest users, United, Trans World and American, clearly illustrates that engine management in the commercial airline industry is an enterprise of sizeable proportions [9:190].

Comparing the Air Force jet engine inventory to the commercial inventory shows that the Air Force owns more than four times the number of jet engines possessed by all of the United States' airline companies combined.

Table 3

Commercial Jet Engine Inventory (9:191)

	All Airlines	United	American	TWA
Installs	7734	1203	823	901
Spares	1044	153	120	99
TOTAL	8778	1356	943	1000

The Air Force uses a Type-Model-Series (TMS) classification/identification system as an aid to managing its large and diverse engine inventory. Appendix F provides information about Air Force piloted aircraft turbojet and turbofan engines by TMS, including the manufacturer of each engine, cost per unit, and the

weapon systems the engine is used on.

As mentioned earlier, the Air Force has dominated turbine engine development. In addition to development, the military has also been the dominant buyer of aircraft engines, while the commercial buyers have comprised a much smaller share of the aircraft engine manufacturer's total sales. As is indicated in Table 4 the commercial sector has been steadily commanding a larger share of the engine market in recent years. If the current trend continues, commercial engine sales may soon equal or surpass military engine sales (9:212). In spite of a reduced share of the total engine market, the military in all probability will continue to lead the turbine engine industry in technological advancement (9:308).

Recent Air Force Institute of Technology research studies. The following research studies were all conducted by students at the Air Force Institute of Technology School of Systems and Logistics. Each study was concerned with some aspect of life cycle cost.

In August 1974 Lawrence E. Dover and Billie E. Oswald published the results of an extensive literature search which they conducted on the subject of life cycle costing techniques and models. Dover and Oswald concluded that awareness of life cycle costing concepts results in better planning and decision-making (32:148). They also concluded that the usefulness of life cycle costing is

Table 4

Aircraft Engine Industry Sales
By Calendar Year (9:213)

($ in Millions)

CALENDAR YEAR	MILITARY	COMMERCIAL	TOTAL
1956	1,562.0	226.7	1,788.7
1957	1,719.0	273.1	1,922.1
1958	1,566.0	232.6	1,798.6
1959	1,325.0	215.7	1,540.7
1960	1,009.0	432.8	1,441.8
1961	1,087.5	404.5	1,492.0
1962	1,080.5	341.7	1,422.2
1963	1,083.0	410.1	1,493.1
1964	1,232.4	362.0	1,594.4
1965	1,296.9	515.5	1,812.4
1966	1,569.0	636.0	2,205.0
1967	2,032.9	901.0	2,933.9
1968	2,056.1	1,111.3	3,167.4
1969	2,108.0	1,002.8	3,110.8
1970	1,905.0	995.3	2,900.3
1971	1,529.0	963.2	2,492.2
1972	1,201.4	904.4	2,105.8
1973	1,289.4	1,070.0	2,359.4
1974	1,618.3	1,243.0	3,061.3

somewhat limited by the complexity of cost models and the difficult task of anticipating all potential costs of sophisticated weapon systems (32:150-151).

Lynn M. Lynch and Neil V. Raymond verified their hypothesis concerning Cost-Estimating Relationships (CER) and life-cycle cost predictions in January 1975. The Raymond and Lynch study established a relationship between certain design variables of inertial measurement units (used in aircraft navigation systems) and the O&S costs associated with maintaining these units. The authors concluded that CER is a valid technique for estimating life cycle costs of subsystems and components (23:53).

In June 1976, Eric E. Nelson and William E. Smith published their research study on cost estimating characteristics of an AFLC aircraft replenishment investment spares model. Smith and Nelson discovered in their research that many cost estimating models presently in use in the DOD are not well constructed and/or are based on partial or erroneous information (28:105).

Finally, Rodney W.J. Mullineaux and Michael A. Yanke completed a thesis on the estimation of jet engine costs in June 1976. Yanke and Mullineaux concluded that current Air Force cost-estimating models are operationally ineffective (27:86-87).

One problem that is identified or alluded to in each of these studies is an inability to accurately

predict O&S costs in the DOD. These studies indicate that one cause of this problem is the lack of adequate O&S cost data in the Air Force.

Research objective. The objective of the research is to identify Air Force data bases which contain operating and support cost data for aircraft engines. Once these data bases are identified, the limitations of the operating and support cost data they provide and their suitability for use will be examined. These data sources will be identified to better enable the Aero Propulsion Laboratory to estimate O&S costs of aircraft engines.

Research questions. The following research questions will guide the research:

1. What Air Force data bases are currently available which contain aircraft engine O&S cost data?

2. What are the limitations of the data contained in these data bases relative to their use in the estimation of O&S costs for aircraft engines?

CHAPTER II

METHODOLOGY

The purpose of this research is to identify and evaluate data bases which can be used to estimate life cycle O&S costs for aircraft engines. The methodology is organized into three sections. The first part defines what elements comprise operation and support costs. The second part describes how data bases were located and the third describes how these data bases were analyzed and evaluated for their suitability for O&S cost estimation of aircraft engines.

Defining Life Cycle O&S Costs

In attempting to locate data bases which contain data suitable for the estimation of life cycle O&S costs for aircraft engines, it is necessary to define O&S costs. Rather than arbitrarily define O&S cost elements, two life cycle cost models, the Working Group Life Cycle Cost Model and the Logistics Support Cost (LSC) Model have been examined. The purpose in examining two models rather than one is twofold: one is to identify O&S costs and second to illustrate that it is possible to group the same O&S costs differently and call them by different names. It is important that the second point be recog-

nized because later in this section O&S costs are regrouped and renamed a third time to more closely correlate to the organization of data bases in the Air Force.

Working group model. This model was formulated by the Aeronautical Systems Division of AFSC specifically for use in determining life cycle costs of aircraft engines during source selection (57:Atch 1). The model takes a micro approach, that is, it uses 53 separate equations to derive separate elements of life cycle cost and these elements are summed to obtain a total figure (57: Atch 1-8). Of these 53 equations, 16 are used to derive the operation and support costs. The elements of O&S costs by equation title are as follows:

1. Training cost
2. Contractor field support cost
3. Data cost
4. Recurring inventory management cost
5. Recurring maintenance management data cost
6. Engine scheduled maintenance cost
7. Engine unscheduled maintenance cost
8. Packaging and shipping cost
9. POL cost
10. Detailed engine design cost
11. Engine manufacturing cost
12. Peculiar Aerospace ground equipment cost

13. Special test equipment cost

14. Contractor test cost

15. Government test cost

16. System Engineering/Project Management cost

A complete breakdown of these equations would be much too lengthy to present here but a more complete treatment of the Working Group Model is presented in Appendix A.

Logistics support cost (LSC) model. The LSC model is an analytical type model in which the various components of a system's logistic support costs are determined at a micro level, then summed to obtain the total system logistic support cost (53:3). The LSC model was developed by AFLC to estimate the expected support costs associated with adopting a particular system design (53:3). The LSC Model Users Guide cautions that judgments should not be made upon the absolute value of the costs, but upon the comparative difference between various alternatives' LSC.

> In this regard, the LSC model is not, strictly speaking, a life cycle cost model although it is one of the many specialized models used to support the technique known as life cycle costing [53:4].

This model uses 95 separate data elements to derive the logistics support cost of a system (53:6). The LSC model is composed of 10 equations, one equation for each type of support that is recognized by the model as

being a portion of total system support cost. The 10 types of support costs are:

1. Spare parts cost
2. On-equipment maintenance cost
3. Off-equipment maintenance cost
4. Inventory management costs
5. Support equipment cost
6. Personnel training
7. Management and technical data cost
8. Facilities cost
9. Fuel consumption cost
10. Spare engine cost

NOTE: On and off equipment maintenance costs refer to whether or not the maintenance was performed while the equipment was on the aircraft or off the aircraft (53:33-34).

Reclassification of O&S costs. It is interesting that both these models identify similar types of costs as O&S costs, although they use different nomenclatures. For example, the working group model classifies maintenance into scheduled and unscheduled maintenance while the LSC model classified it into on and off equipment maintenance. It would be convenient if it was possible to use these classifications of O&S costs for this study. A review

of the literature (11:18-22) and preliminary research showed that using these classifications is not possible. This is so because data bases in the Air Force are not designed to collect data by the same classifications that are used by the models (53:6-7). Therefore, it is necessary to develop O&S data classifications which more closely parallel those found in the Air Force data systems. Table 5 is a listing of these classifications. These individual components of O&S costs for aircraft engines in the Air Force will be developed more fully in later sections of this study.

Locating data bases. Initially, Air Force Publications were searched. These publications, in the form of Regulations, Manuals and Pamphlets, set forth major policy and procedures for all Air Force activities. The search of these publications was simplified because they were organized into topical series and each series has a distinct numerical designation. For example, the aircraft maintenance system is detailed in the 66 series, the 400 series deals with logistics management, and the 173 series deals with cost analysis (48:1-2).

Most data bases were located through this search of publications. Since cost reduction has been receiving increased emphasis in the past few years, valuable sources of operating and support cost data which are not in the Air Force Publications were found to exist.

Table 5

O&S Cost Classification

- Base level maintenance
  - Materiel
    - Spare parts
    - Expendable materiel
  - Labor
  - Overhead
  - Transportation expense of items sent to depot
- Depot level maintenance
  - Government maintenance
    - Materiels
      - Spare parts
      - Expendable supplies
      - Modification kits
    - Labor
    - Overhead
  - Contractor furnished maintenance
- Component Improvement Program (CIP)
- Fuel costs
- AGE costs
- Spare engine costs
- Training costs
- Data costs

Therefore, information which can be found in the following sources were included in this research effort:

1. Official Air Force reports and submissions.

2. Recorded, unpublished backup data for official reports.

3. Special studies by individuals or outside agencies (RAND reports).

4. Actual cost records, i.e., budget records, auditor reports, etc.

5. Expert opinion and advice.

Once a data base containing O&S cost information was located, the office of primary responsibility for that data base was contacted. This contact was personal, if possible and telephonic if not. After contact was made specific information for use in the analysis of the data base was obtained. The types of questions which were asked to obtain this information are included in the second part of the methodology.

It is possible that engine O&S cost data exist throughout the Air Force in many different agencies. Due to time limitations, it was not possible that all agencies could be contacted. Therefore, the data search was conducted primarily in the Headquarters, Air Force Logistics Command (AFLC), since AFLC is chartered by the Air Force to support the operating commands (37:200). One other interesting and useful source of data was the

Engine SPO, Aeronautical Systems Division, Air Force Systems Command, at Wright-Patterson Air Force Base, Ohio.

Analysis of data bases and determination of suitability for O&S cost estimation. Once data bases were located, information was obtained so that they could be analyzed. This information was gathered by examination of the directives which established the data base and discussion with the personnel who manage the data base. The following types of information were included in the analysis of the data base:

1. The purpose for which the data base is used. It is important to know whether a data base is intended for use in accounting for costs, maintenance management, safety improvement, reliability improvement, etc. The ideal situation would have been to find a data base established for use in life cycle costing, but since no data bases of this nature were found, a description of its intended use may provide some insight into what type of cost data the base contains.

2. Cost elements which the data base contains. A complete understanding of what cost elements are included in the data base is essential to the analysis of the data base.

3. How the cost data is collected, i.e., where do the cost elements in the data base come from. This portion of the analysis describes whether the cost data

are actual accumulated figures or estimates or perhaps some standard figure used throughout the Air Force. If the data are actual accumulated, estimated, or standard how have they been accumulated, estimated or standardized will be described.

4. The format of the data was described.

5. The form, i.e., microfiche, microfilm, computer printout, etc., was described.

6. The frequency of the data production is given.

After the data base is analyzed it was evaluated as to its usefulness for the estimation of aircraft engine O&S costs. This evaluation considers the following items:

1. How complete is the cost data? Is the system designed to account for all support costs? If not, which elements are not included?

2. How reliable is the cost data? Are cost data consistently and accurately reported? Are computations performed upon the cost data consistently and accurately applied?

3. How valid are the cost data contained in the data base? Are all data included as O&S cost data appropriate for inclusion as O&S cost? Are all assumed values, constants, and standard cost factors valid?

4. Are cost data in sufficient detail to allow O&S cost estimation for aircraft engines? Are data reported at the total system level or to some subsystem

level?

5. What performance measures are available to determine the quality and quantity of data input? What tools are available to gauge the quality and effectiveness of the data contained in the data base?

6. Are there any other problems, such as any design limitations, procedural problems or any type of errors which adversely affect the quality of the O&S cost data?

The preceding data base analysis and evaluation is intended to give potential users of the data base a more complete understanding of the good and bad features of that data base. Then, when users attempt to estimate aircraft engine O&S costs, they will have a much clearer idea of possible weaknesses in their estimates.

Summary. The methodology included a plan to search for, analyze and evaluate data bases which contain O&S cost data for aircraft engines. This plan was sufficiently detailed to ensure that adequate information was collected for use by personnel at the Aero Propulsion Laboratory yet the plan proved flexible enough so that the researchers could fit the procedures to whatever type of data bases were found.

CHAPTER III

FINDINGS AND RESULTS

Introduction

The cost to operate and support an engine over its entire life cycle is, of course, a large amount of money. Trying to estimate to any degree of accuracy what this cost will be for a new engine is a monumental task fraught with many difficult problems. Perhaps the first problem would arise when deciding what costs associated with operating and supporting an engine should be identified for forecasting. While it might be possible to identify all of the costs of operating and supporting an engine, the time and resources expended to obtain estimates of these costs may not be reasonable. In fact, spending a great deal of time and money to estimate accurately an operating and support cost that represents less than one percent of an engines life cycle cost, when another significant operating and support cost can vary between 30 to 50 percent of the total life cycle cost, makes no sense at all.

For the purposes of this study, the operation and support costs which will be considered are maintenance costs, Component Improvement Program costs, auxiliary ground equipment support costs, and fuel and oil costs.

Also, since maintaining an inventory of spare engines represents an operating and support cost, actuarial data and its uses in engine management will be discussed. The areas of data cost and training costs are excluded.

These areas were selected for inclusion or omission based upon the review of literature, interviews and past studies on the estimation of O&S cost. In three independent O&S cost studies, the major costs were maintenance, CIP, AGE, fuel and oil and spares while data costs and training costs each comprised less than one percent of the total O&S costs (9;11;29).

The remainder of this chapter will be organized by the topical areas just discussed, with one exception. Maintenance will be further broken out into two subgroupings, base level and depot level maintenance. This distinction is necessary because jet engine maintenance in the Air Force is performed at these two levels (29:118). Base level maintenance can actually be broken down into Organization Maintenance and Jet Engine Intermediate Maintenance (JEIM). "Organizational Maintenance includes engine servicing, replacing minor external components and installed engine inspections on the flight line [9:160]." JEIM includes all maintenance performed in the base jet engine shop (9:160).

> The extent of JEIM is constrained by authorized tooling, availability of technical data, and level of disassembly authorized in the field. Quick Engine

Change (QEC) kits and afterburners are also maintained at JEIM since neither are regularly scheduled for return to the depot for overhaul or major repairs [9:160]

Depot maintenance activities can be said to be the last step in jet engine maintenance. "Depot maintenance provides the capability to completely disassemble, inspect, repair as necessary, reassemble and test the complete basic engine [9:160]." Depot maintenance for jet engines is performed at two central locations, San Antonio Air Logistics Center and Oklahoma City Air Logistics Center.

Each topical area will be organized in the following manner. First the topical area itself will be described and including the rationale and function of the particular O&S area. The organization which has primary responsibility for the data base and where the data comes from will also be described. An analysis of the data base will then be presented. It will include a description of the purpose of the data base, the cost elements in the data base, the format of the data base, and who uses it. Then the data base will be evaluated on its completeness, reliability, validity, detail, design limitations and procedural problems (a more complete discussion of data base analysis and evaluation is contained in the methodology).

Maintenance Costs

Base level maintenance costs. Base level engine maintenance costs consists of all labor and parts consumed in maintaining engines at the base. At the present time, there are few cost measures or cost controls for the maintenance manager at base level (9:180-181). His primary concern is ensuring that enough engines are operationally ready to fulfill the base sortie requirements (9:181). There is one program which does compute logistics support costs for weapon systems in the Air Force, the Increase Reliability of Operational Systems (IROS) program. Presently, it is the only system which collects the logistics support costs of a weapon system. The IROS program attempts to account for packaging and shipping costs, base level maintenance costs and depot level maintenance costs. This section will describe how the IROS system collects and computes costs, who has functional control over the system, and why it is not recommended for use in estimating depot repair costs.

The IROS program is prescribed by AFR 400-46, Increase Reliability of Operational Systems (IROS) Program and AFLCR 400-16, same title. The program's objective, according to AFLCR 400-16, is to:

> Quantitatively assess, predict, and improve the effectiveness of weapon/support systems in the following manner:
> a. Measuring and tracking the performance,

> reliability, maintainability, safety and logistics support costs of items [52:1].

AFLCR 400-16 further defines logistics support costs as:

> costs associated with supporting an item, to include (when obtainable) costs of base labor, base material, costs to replace condemnations, transportation and shipping costs for non-base reparable items, technology repair center costs and others when the cost is quantifiable [52:2].

The IROS data system, which supports the aforementioned objectives, is called the KO51 report. The KO51 report is prepared quarterly (53:2) and contains 4 major segments (53:2). The first segment is the logistics support cost data. This segment will be discussed in detail later in this section.

The second segment is the availability ranking. There are five products in this segment: the rank sequence by aircraft number (KO51.30RA), the rank sequence by work unit code (KO51.30RW), the high degradation rank unit code (KO51.30ROR), the system degradation work unit code sequence (KO51.30FW), and the system degradation serial number sequence (KO51.30FA) (53:6). The availability data compares the number of systems operationally ready with those which are not operationally ready (53:44). A system may be not operationally ready for four major reasons (53:44):

NORS (Not Operationally Ready-Supply)
NORM (Not Operationally Ready-Maintenance)
GAB (Ground Abort)
FAB (In-Flight Abort)

The availability data is used to highlight items which are unreliable and contains no cost data.

The third segment of IROS data is flight safety prediction data, which at the present time is undergoing development. There are no products currently available (53:6).

The fourth segment of IROS data is feedback of operational performance and logistic support histories to AFLC system and item managers, AFSC system program managers, and civilian aerospace contractors for use in the design of new systems (53:60). This segment contains no cost data.

This study will focus on only one of the four segments of IROS data, the logistics support cost data. There are nine logistics support cost data products which are listed in Table 6.

There are 10 different data systems which input into the IROS system (36). Of primary importance to the logistics support cost segment are the G001B Maintenance Data Collection System (commonly referred to as 66-1 data, since it collects all the maintenance data for the maintenance prescribed in AFM 66-1), the G033 Aerospace Vehicle Inventory and Equipment Status Report, and the G098 Programmed Depot Maintenance Interval Analysis report (11:1-2; 52:10-11). These systems report data on 41 aircraft, 3 missiles and 55 communications-electronics-

Table 6

Logistics Support Cost Products (53:6)

KO51.PN1L	"Logistic Support Cost Ranking Selected Items"
KO51.PN2L	"Equivalent Rate Ranking Selected Items"
KO51.PN3L	"Logistic Support Cost Ranking Work Unit Code Status"
KO51.PN4L	"Logistic Support Cost Breakdown Current Quarters Computations
KO51.PN5L	"Equivalent Rate Ranking Work Unit Code Status"
KO51.PN8L	"Logistic Support Cost File Maintenance Register"
KO51.PW2L	"Logistic Support Cost Ranking Item Manager Federal Stock Number Status"
KO51.PW4L	"Logistic Support Cost Ranking Weapon System Correlation"

meterological systems and equipment (53:41-42). Table 7 is a listing of the aircraft and missiles which are covered by the IROS data system.

Table 7

Systems Included in IROS (53:41-42)

Bombers	Fighters	Reconnaissance
B-52G	A-7D	RF-4C
B-52H	A-37	
B-57	F-4C	Cargo
FB111A	F-4D	C-5A
	F-4E	C-9A
Trainers	F-100	C-130A
T-29	F-102	C-130B
T-33	F-104	C-130E
T-37	F-105B	AC-130H
T-38	F-105D	C-131
T-39	F-105F	KC-135A
	F-106	
Drones	F-111A	Helicopters
BQM-34A	F-111D	UH-1F
BQM-34F	F-111E	UH-1N
	F-111F	CH-3C
Missiles		HH-43
AGM28	Special	HH-53C
AGM69	OV-10	
LGM30	O-2	

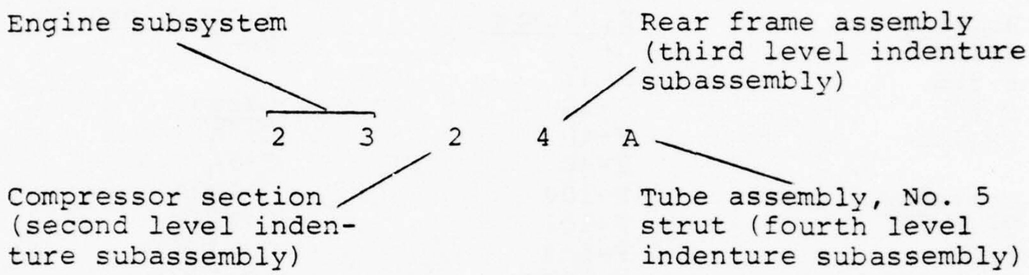
The IROS data is presented by Work Unit Code (WUC) since the 66-1 maintenance data is reported by WUC, so it is necessary to present a brief background of the WUC system so that the reader can gain full benefit from the discussion of the IROS data. The WUC provides a method of complete identification of a system down to it's lowest level component and is similar in function to the Work Breakdown Structure (MIL-STD-881) used by the prime

weapon system contractor (53:8).

All WUC's are composed of a five character alpha-numeric designator. Consider Figure 10 which is a WUC for a part on the F-4E.

Figure 10

Example Work Unit Code (42:23-003)



The source for this WUC is T.O. IF-4E-06 (42:23-003) which contains all of the Work Unit Codes for the F-4E aircraft. This WUC, 2324A, represents the No. 5 strut of the tube assembly in the rear frame assembly in the compressor section of the F-4E's engine. The WUC for the No. 6 strut is 2324B. The actual number of WUC's assigned to an aircraft may vary from one type of aircraft to another. For example, the A-7D has 3,260 Work Unit Codes while the C-5A has 10,700 (53:14). For all aircraft, however, any WUC beginning with 23 belongs to the turbojet or turbofan power plant of whatever aircraft it happens to be (46:21). If a maintenance person at a base works on the No. 5 strut of the tube assembly, he would record

the number of hours he worked against that WUC (in this case 2324A). This means that if we desire to know the amount of maintenance done on an engine we need only to look at the hours assigned to the 23XXX series work codes. Since the work codes are so important, a listing of WUC system codes is provided in Appendix C.

Now that a brief background of WUC's has been presented, the costs included in the IROS data will be discussed. Figure 11 is a graphical representation of these costs. If one were to represent these costs in equation form this is what the equation would be (53:5):

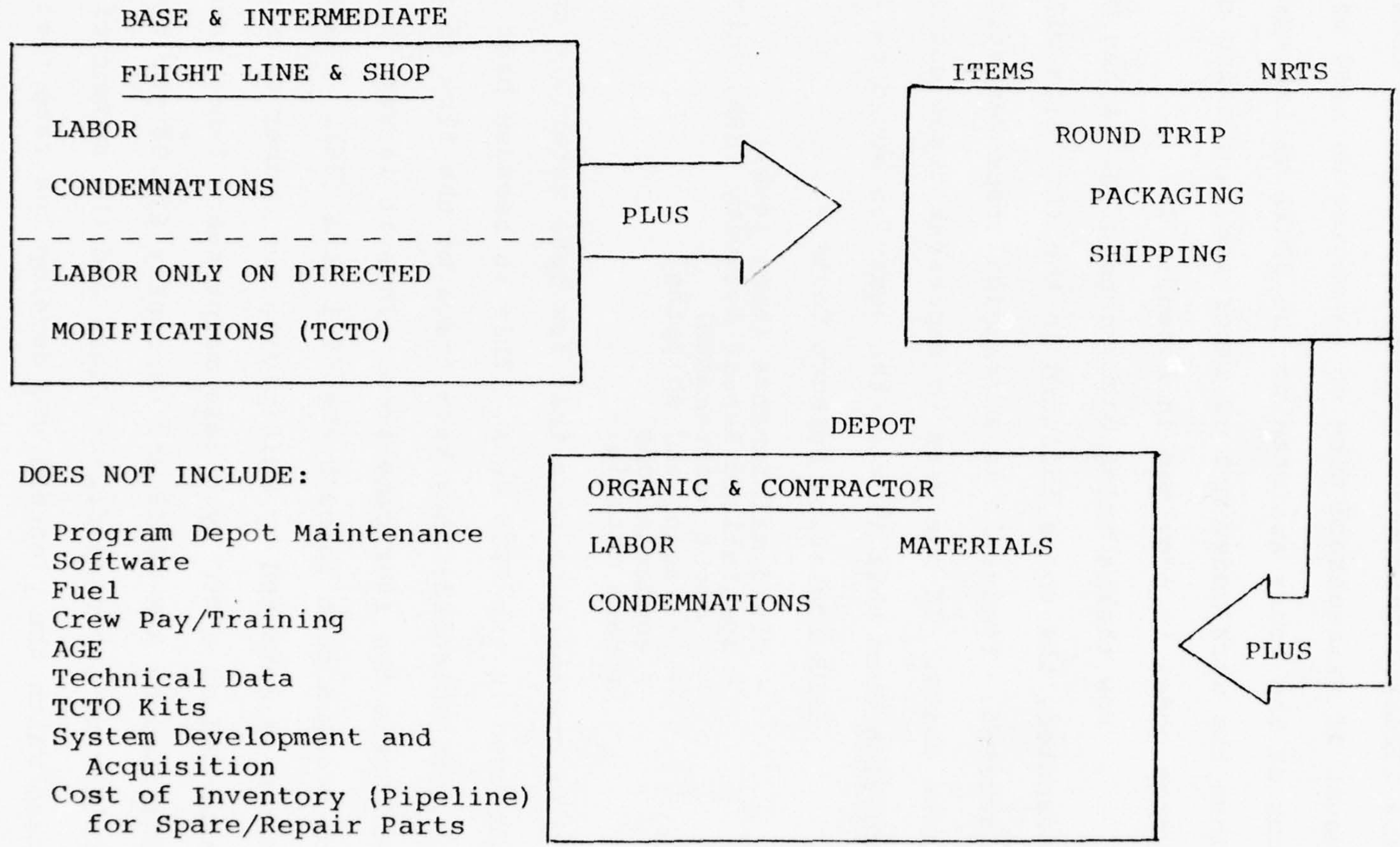
IROS Logistics Support Costs =

+ field maintenance (base level)
+ Specialized Repair Activity (SRA, which is depot maintenance)
+ packaging and shipping
+ condemnations
+ base materials

It is important to note that few base materials costs are captured in the IROS data. This is because base supply is item oriented; they keep track of the flow of items, not where the item came from. Thus it is very difficult to trace a part through the 66-1 data (36). Field maintenance is computed by multiplying the number of manhours expended on a WUC by a base maintenance labor rate (defined by AFM 66-18 and currently $14.00 per hour [36]). This rate includes direct wages and the amount of overhead which the planners who develop the rate feel should

Figure 11

IROS Cost Components (53:13)



DOES NOT INCLUDE:

- Program Depot Maintenance
- Software
- Fuel
- Crew Pay/Training
- AGE
- Technical Data
- TCTO Kits
- System Development and Acquisition
- Cost of Inventory (Pipeline) for Spare/Repair Parts

be allocated to maintenance (36). Packaging and shipping costs are a round trip cost based upon the number of items shipped to depot and the cost to ship them (36). The condemnation cost is based upon the number of items condemned times the unit price of the item (36). The SRA (or depot maintenance) is computed by multiplying the number of items sent to depot (NRTS or Not Repairable This Station) minus the items condemned at depot by the standard repair cost of an item at depot (53:5).

Now that we have examined what cost data are included in the IROS data we can examine the IROS data products. IROS data is organized by aircraft Type-Model-Series (TMS). The data samples which are presented here and in Appendix E are for the A-7D, which has one TF-41 turbofan jet engine. IROS data are updated continuously in the computer but the products are produced quarterly (53:2). The IROS data is on microfiche only (36) and can be obtained at AFLC/LOLMA, telephone number 257-4963.

The K051.PN1L, Logistics Support Cost Ranking Selected Items report provides the logistics support cost ranking by WUC for all WUC's down to a logistics support cost of $750. An example of this report can be found in Figure 21 in Appendix E. On this sample, the TF-41 engine WUC of 23100 ranked fifth in logistics support costs, needing $63254 per month or 2.491% of the weapon system's total logistic support costs. The report also

indicates the WUC's ranking for the last 3 quarters as well as the dollar amounts for this quarter. This report provides the manager with an indication of any fluctuation in required logistics support costs, but since it includes the IROS estimate of depot costs, it is not recommended for use in estimating a systems total logistics support cost.

The K051.PN3L Logistics Support Cost Ranking Work Unit Code Status report provides a logistics support cost for the system and subsystem level. A sample of this report can be found in Figure 22, Appendix E. As is indicated, the TF-41 turbofan engine consisting of all 23XXX WUC's used 6.790% of total system logistic support cost or $172,446 per month. This report is more convenient than the PNIL report because it groups all subsystem WUC's, but it is not recommended for use because it contains the IROS estimate for depot maintenance also. Figure 23, Appendix E is a continuation of the PN3L report in which each subsystem WUC's are listed in numerical order. It is used to identify logistics support costs for all individual WUC's and is provided for informational purposes only.

The PN4L Logistics Support Cost Breakdown Current Quarter Computation is significant in that it provides a breakdown by WUC of the cost elements of logistic support cost. Figure 12 is a sample PN4L report for the quarter

Figure 12

Logistic Support Cost Breakdown
Current Quarter Computation

N 08
WEAPON SYSTEM ADD7D OCALC LOGISTIC SUPPORT COST BREAKDOWN RCS LOG-MMO(Q) 7213(3) KO51.PN4L PAGE 24
AFM 65-110/66-1 DATA AS OF 76 JUN CURRENT QUARTER COMPUTATION DATE PROCESSED 76 AUG 01

		QUARTERLY VALUES				
WUC	NOUN	FIELD MAINT	SPEC REPAIR COST	PACK-SHIP COST	CONDEMNATION COST	TOTAL QTR LSC
23000	TURBOFAN PROP S	$1,299	$0	$0	$0	$1,299
230XX		$1,299	$0	$0	$0	$1,299
23100	TF41 ENGINE	$76,873	$102,882	$10,006	$0	$189,761
231A0	LP IP COMPRESSO	$90	$0	$0	$0	$90
231AA	INLET ASSY ENGI	$120	$0	$0	$0	$120
231AB	EXTENSION AIR I	$1,387	$0	$0	$0	$1,387
231AC	PROBE TEMP T1 P	$67	$0	$0	$0	$67
231AF	SUPP AS FRT LP	$56	$0	$0	$0	$56
231AG	WHEEL AS LP COM	$840	$0	$0	$0	$840

ending 30 June 1976. For the WUC 23100 TF-41 engine the field repair cost (base maintenance) was $76,873, the specialized repair cost (depot maintenance) was $102,882, the packaging and shipping costs were $10,006 and the condemnation costs were $0. This data can be used since depot costs are separated out from the other costs. If one wished to determine the quarterly base maintenance cost for the TF-41 engine fleet, he would simply sum the individual repair costs for each engine WUC. One important note is to remember that while the PNIL and PN3L reports display <u>monthly</u> costs, the PN4L displays <u>quarterly</u> costs. In this example, the total <u>quarterly</u> logistic support cost for the 23100 WUC is $189,761, which is three times the monthly logistics support cost shown for the 23100 WUC in the PNIL report.

The following two reports are included primarily for informational purposes. The KO51.PN6L Logistics Support Cost Ranking National Stock Number Status report. This report is made available so that a manager who needs logistics support costs by national stock number can find them. The KO51.PN7L Maintenance Action Summary report provides the number of maintenance actions recorded against a given WUC or national stock number (NSN). A NSN of all 9's means that the NSN does not exist or that maintenance was performed while the item was on equipment, in which case no part number is recorded. A sample of

each of these reports is found in Appendix E. Figure 24 is a sample of the KO51.PN6L and Figure 25 is a sample of the KO51.PN7L.

In evaluating the IROS data two important points about the entire system must be remembered. The first point is that the logistics support cost reported in the IROS data will be conservative because, by definition, the logistics support costs included in the IROS system are not the system's total LSC (fuel, for example, is excluded) (53:6-7). The second point is that the logistics support costs as reported in the IROS system are heavily keyed to cost factors. The base maintenance labor cost is keyed to the $14.00 per hour standard base labor rate as prescribed in AFM 66-18 and the depot repair costs are keyed to the standard repair rate for depot items. As far as the researcher could determine from the literature and interviews, there is nothing intrinsically wrong with these factors.

The remainder of this evaluation will consider the data base by cost type, i.e., base level maintenance, depot level maintenance, and packaging and shipping costs. The evaluation will consider data accuracy and detail.

The evaluation of base level maintenance data shows that the data have some accuracy problems. The biggest single problem with accuracy at the base level is a reporting problem (21). Several persons were inter-

viewed who worked with 66-1 data both from the maintenance field and from the data management field and no one had very much confidence that maintenance data was being reported correctly from the field (36;21). The second problem with 66-1 data is that many times items are repaired in shops where the labor expended is never traced to the item (21). An example of this would be a part of an engine sent to the base welding shop or a part sent to the sheet metal shop.

The detail to which the logistics support costs are collected is very good. The WUC identification system enables one to collect data on very small subassemblies of an engine. The organization of WUC's into consistent subsystem identifiers (i.e. any WUC's beginning with 23 comes from the engine) makes the aggregating of system costs by subassemblies very easy.

The next area is the specialized Repairs Activity (SRA) or depot level maintenance. This estimate of logistics support costs for depot maintenance is not considered to be of sufficient quality for use. The method of computing these costs is less than ideal (that is, multiplying a standard repair rate times the number of items which were reported as NRTS). First of all, there is evidence that the number of items reported as NRTS in the IROS data base is conservative (36). There is another data system which reports engine NRTS (Under

AFM 400-1 Selective Management of Propulsion Units, Policy and Guidance, the data is reported for actuarial purposes [36]) and this system, which is considered to be the most accurate data system on engines in the Air Force, consistently reports significantly more engines NRTS than the IROS data (36). Since the NRTS rate is the key to the depot costs, the researchers think that the depot cost data to be too unreliable for use. Fortunately, there is a data base which more accurately reports depot costs, so one is not dependent upon the IROS data. This data base will be described later.

In the area of packaging and shipping, the same problem is encountered with the accuracy of these data as with the accuracy of the depot data, that is, they are keyed to the engine NRTS rate. The data are reported by WUC so that they are in sufficient detail for use.

The condemnation costs are computed by using the replacement cost of the new item which replaced the condemned one. There is only one problem with this method; that is, there is no standardized cross-reference between WUC's and national stock numbers (NSN) (36). Unit costs are listed by NSN's so that occasionally the replacement cost of an item listed by WUC is not computed (36). The detail in which condemnation costs are given is satisfactory for use in O&S cost determination.

<u>Depot maintenance costs</u>. As previously discussed, engine maintenance in the U.S. Air Force is performed at two levels; base and depot. The largest percentage of engine maintenance costs are expended at the depot level (29:120). "The primary function of the USAF engine depot is to overhaul engines and accessories to restore them to what is termed a 'zero-time' status [29:119]." Zero-time being the state in the life cycle of an engine when the engine has been completely overhauled and has zero operational flying time. Engine maintenance in the Air Force is based on a "hard-time" philosophy where maintenance activity is directed when an engine accumulates a specified number of flying hours. This maintenance is required regardless of how the engine is performing when the specified flying hours are accumulated. The maximum flying hours allowed on a specific engine is greatly dependent on the mission environment in which it operates. Fighter aircraft, for example, place more stress on their engines (e.g. high "g" forces, rapid power changes, operation in high power settings, etc.) than do bomber or transport aircraft and therefore have relatively low maximum operating time limitations. The difference in the maximum operating time allowed for a fighter engine as opposed to a transport or bomber engine can be seen in Table 8, which is a partial listing of USAF engines and the maximum operating hours allowed before the engine must be

Table 8

Engine Operating Time Until Overhaul - Selected Engines (43)

Engine Models	Aircraft	Maximum Operating Hours
J33-35	T-33	7500
J47-27	F-86	1100
J57-19/29	B-52	4000
J57-21	F-100	1200
J57-23	F-102	1500
J57-43	B-52/KC-135	4000
J57-59	KC-135	4000
J60-5A	C-140A	4500
J60-9(POD)	RB-57F	1500
J65-5F	B-57	1500
J69-25	T-37	3000
J75-17	F-106	1200
J75-19W	F-105-D/F/G	1200
J79-11A/B	F-104,A,B,G	800
J79-17	F-4E	1200
J85-5B/C/D/E/F/G/H	T-38	2400
J85-13	F-5A	2400
TF30-1	F-111	300
TF30-3	F-111A/E	1000
TF30-9	F-111D	1000
TF30-100	F-111F	850
TF33-3	B-52	4000
TF33-5	C-135-B	8000
TF33-7A	C-141	12000
TF39-1	C-5A	1500/2000
TF39-1A	C-5A	5000
TF41-1	A-7D	750
T56-7B	C-130B/E	4000
T76-10/12	OV-10A	2400
TF41-1A	A-7D	1000

completely overhauled (a ten percent margin over the maximum is allowable).

The major depot cost is attributed to the function of "zero-timing" an engine and begins with a complete engine disassembly; the parts removed are then reworked, modified, or condemned and replaced by new parts (29:120). When the entire engine is finally reassembled at the completion of the depot overhaul, it is considered to be a zero-time engine ready to be flown to its maximum operating time. In this manner, the depot restores to the operating fleet some amount of the flying hours consumed in a given year (29:120).

> There are besides this primary function, several additional engine-related repair activities at a depot which are not associated with the classical whole-engine overhaul. These activities include immediate correction of hardware deficiencies which are causing safety of flight problems in the fleet and which could result in grounding of the fleet; minor repairs of engines which do not need major repairs, but such repairs must be accomplished at a depot rather than a base; modifications to engines to replace parts which have been obsoleted for deficiency or reliability reasons; repair of reparable parts and accessories sent in from the field; and replacement of those reparable parts and accessories which are condemned. In general, depot repair activities are those which cannot be accomplished at an operating base [29:120].

As previously discussed, the IROS data system attempts to collect depot maintenance cost. Another Air Force data system for collecting depot maintenance costs is the HO36B system. The HO36B data system is used by Air Force Logistics Command (AFLC) Headquarters to

forward depot repair costs to the DOD. The data is obtained from the following sources: GO72A (organic or "in-house" depot maintenance costs), GO72D (contracted depot maintenance costs), HO73 (training, technical assistance, and other depot maintenance support costs), DO33 (standard inventory prices), and HO36A (Air Logistics Center processing costs). Recently, the DOD decided that all depot maintenance activities should utilize uniform cost accounting systems. DOD Instruction 7220.29 was issued in October, 1968 to initiate the change to a uniform cost accounting system (60:100-101). The original DODI 7220.29 was cancelled in October 1975 and DOD 7220.29, Handbook, became the governing document for changing to a uniform cost accounting system. This handbook applies to all Army, Navy, Air Force and Marine Corps activities performing depot maintenance and maintenance support (60:100-101).

> The principle objective of this Handbook is to establish a uniform cost accounting system for use in accumulating the costs of depot maintenance activities as they relate to the weapon systems supported or items maintained. The Handbook provides principles and procedures to assure uniform recordation, accumulation, and reporting of on depot maintenance operations and maintenance support activities. The cost system will be controlled by a double-entry, accrual-based general ledger accounting system [60:110-111].

A job order cost accounting system is used to gather depot maintenance costs in the HO36B system.

> A job order system is a method of cost accounting whereby costs are compiled for a specific quantity

> of product, equipment, repair, or other service that moves through the production process as a continuously identifiable unit. The applicalbe material, direct labor, other direct costs, and the portions of overhead are charged to specific job orders [60:310-311].

A pure job cost system assigns costs to each individual job worked on. The HO36B data system will assign job orders in accordance with the following criteria:

A. Work may be controlled and accounted for by separate job orders as desired; but, as a minimum, individual job orders will be established by the performing activity in accordance with the following criteria:

   1. Units subject to "preshop analysis" or examination and evaluation:"

      a. A separate job order is required for each unit when the estimated cost of maintenance to be performed is in excess of $60,000;

      b. A job order is required for each month's inductions of units having the same identification number (TMS or NSN) and the estimated cost of maintenance to be performed is from $10,000 to $60,000 per unit;

      c. A job order is required for each quarter's inductions of units having the same identification number (TMS or NSN) and the estimated cost of maintenance to be performed is less than $10,000 per unit.

   2. Units not subject to "preshop analysis" or "examination and evaluation:"

      a. A job order is required for each month's inductions of units having the same identification number (TMS or NSN) and the estimated unit maintenance cost is $10,000 or more;

b. A job order is required for each quarter's inductions of units having the same identification number (TMS or NSN) and the estimated unit maintenance cost is less than $10,000 and the planned work on all items scheduled for induction during the quarter is $250,000 or more;

c. A job order is required for each quarter's inductions of homogeneous groupings of items by stock classifications or repair categories where the estimated unit cost is less than $10,000 and the planned work on any one identification number (TMS or NSN) is less than $250,000. The dollar limit for the quarterly group job order is $500,000.

B. The requirement for the performing activity to establish individual job orders for each item does not mean that the financing appropriation must issue a project order or other work authorization for each job order. Rather, the project order or work authorization may be for any number or type of items to be inducted for any time period available to the financing appropriation.

C. Separate job orders will also be established by the performing activity for:

1. Each lot or group of items processed through an operation where direct labor and material costs are not initially charged to the specific unit undergoing depot maintenance, but are later distributed to all units benefiting from the process. Examples are plating and painting operations.

2. Each cost center established for control of indirect costs.

3. Each special non-end item job, such as engineering support, preparation of technical manuals, etc. It is necessary to segregate non-maintenance work from maintenance work and maintenance support from the balance of maintenance work. Job orders will be used for this purpose.

D. Miscellaneous cost accumulations that are necessary for separate accumulation of cost

elements or functions that should be controlled separately from the preceding job order categories. Such cost accumulations are necessary for reduction or cancellation of ongoing maintenance work in order to avoid unreasonable distortion of unit cost of work already accomplished.

E. Under no circumstances will material, labor or indirect costs be charged to job orders based on programmed amounts, or as reservations of materials are made, or as obligations are incurred. Amounts will be charged to the job orders only as work is performed.

F. Job order opening and closing criteria are:

1. Job orders will be opened upon receipt of "Work Authorization" documentation (letter of intent, project order, contract) for maintenance of a specific equipment end item or other item, or when the item(s) are delivered to and accepted for induction by the depot maintenance activity.

2. Job orders will be closed to further direct charges not later than 15 working days (60 days for ships) after all work on the end item or routed component (whichever is later) has been accomplished and final inspection completed. At the end of the month in which the direct charge closing occurs, the job order will be provisionally closed as work in process using the predetermined overhead rates. At fiscal year end, the under/over absorbed overhead will be distributed to orders worked on during the fiscal year. Any transfers of costs to or from provisionally closed job orders must be adequately justified and approved by the activity Comptroller.

3. Adjustments to costs of prior years will still be necessary despite attempts to assure that all costs incurred have been charged to the correct job order prior to its closing. When this occurs, such adjustments will be made to a general and administrative overhead account, "Adjustments to prior year job orders," unless the adjustment would change the total incurred general and administrative expenses more than one-tenth of one percent

for the year in which it is recorded. If the adjustment would result in such a change, then the adjustment will be made to the general ledger account "Adjustment to costs of prior year" [60:310-1-3].

Labor costs are a major cost element of depot maintenance activities. Civilian and Military labor are costed in the HO36B data system as follows:

Civilian Labor

A. All civilian labor hours worked, whether classified as direct or indirect labor, will be costed. Civilian labor hours will be costed at current pay rates plus the cost of: (1) annual leave accrued and sick leave or other leave taken; and (2) Government contributions for employee benefits such as retirement, life and medical insurance. These acceleration factors will be determined by use of appropriate rates.

B. Average labor rates may be used for cost centers where the range of actual pay rates is limited so that distortion of cost is minimal. Otherwise actual labor rates will be used. Stabilized rates used for billing purposes will not be used for costing unless they are coincidently the actual or average labor rates.

C. A labor distribution system will be used to charge all direct labor hours and costs to applicable job orders. Differences between labor hours recorded for pay purposes and payroll costs, and the labor hours and costs distributed to jobs through the labor distribution system will be corrected each pay period. The payroll costs are controlling and errors will be corrected in the direct job order charges or indirect costs. Only the differences due to the use of average cost center rates for costing should be charged to overhead.

Military Labor

A. Military labor hours worked, whether classified as direct or indirect labor, will be charged as unfunded costs to appropriate work orders and/or accounts. Military labor hours will be costed at

.00077 for enlisted personnel and at .00070 for officers of the annual composite standard rates provided in the right-hand column of tables 252-1 to 4 of DOD 7220.9-H (reference (g)). These rates provide for the accelerations established by 25207.C. of reference (g). Time spent on military duties will not be costed.

B. Labor performed by "ship's force" (Navy crew members) loaned to and working under the supervision of the depot maintenance activity when a ship is undergoing depot maintenance in a shipyard is considered depot maintenance. When the ship's force is not loaned, effort is considered organizational maintenance

Civilian leave, fringe benefits (i.e. retirement, insurance, health benefits, etc.), overtime and other premium pay are all costed in the HO36B data system. Material costing, another significant cost element in depot maintenance activities, is accomplished in the HO36B system through utilization of the following criteria:

<u>Inventories of Material</u>

A. All material and supplies on hand at a depot maintenance activity will be accounted for as inventory and controlled by use of the general ledger account provided for that purpose. This inventory account will be credited upon issue (charge) of direct material to a job order for maintenance requirements and a debit made to work in process. Indirect material will be charged to the using cost center upon issue. "Shop stocks" of indirect material should not exceed the average monthly issues requirement. Depot maintenance inventories will be valued at current catalog list prices or at acquisition cost for non-catalogued items. Charges to job orders and credits for returns will also be at the current standard catalog or acquisition prices.

B. Depot maintenance material and supplies inventories will be adjusted at least quarterly to current standard catalog prices. Adjustments due to

repricing will be charged or credited, where practicable, to the lowest level of indirect cost, and where no lower identification is practicable to the general and administrative expense account, "Gains and losses from supplies and material price adjustments."

Customer-Furnished Material (Unfunded)

A. Material furnished by customers is to be included in the depot maintenance work as specified by the customer, and accountability maintained as directed by the customer. Customer's determination of costs will be based on current standard catalog price or acquisition price for non-catalogued items.

B. Customer-furnished material will be costed as an unfunded direct material cost. Any residue of customer-furnished material upon completion of the job order will be disposed of as directed by the customer. Inventory abandoned by the customer and not immediately turned over to the supply system for disposal should be charged to inventory and credited to the general ledger capital account "Contributed Capital."

Direct Material

Direct material is that material which is specifically required for the performance of maintenance as specified by a work authorization document. Small items of insignificant value may be treated as indirect material. Direct material will either become part of the end item or other item which is undergoing maintenance or be consumed in the maintenance process.

Indirect Material

Indirect material is that material which is required in the overall maintenance function but is not specified by a work authorization document for a particular direct job order. Any direct material item of minor dollar amount may be treated as indirect material if the practice is consistently applied and achieves substantially the same results as if the cost had been treated as a direct material cost. The dollar amount of indirect material that is not consumed (i.e., on hand in a cost center) at any one time should not

exceed the average monthly indirect material charges to the cost center for the preceeding year. The unused amount should be analyzed at least once each year and apparent excesses reviewed. Where amounts on hand are determined to be in excess of needs, the requisition/issue amounts will be reduced. If $100 or more is involved in an individual cost center, the excess material will be transferred to the inventory account and indirect expenses reduced.

Material Returns

Unused material returned to the depot maintenance inventory will be credited to the job order originally charged whenever possible. If that is not possible because the job order has been closed in prior years, then the lowest level of indirect costs practicable will be credited, and where no lower identification is practicable the general and administrative expense account, "material credits to prior year job orders," will be credited. The material will be held in the inventory account until it is issued for use on another job or it is determined that it is excess to the need of the depot maintenance activity, i.e., either historical records or projected work requirements indicate that there will be no future need for the item. If the item is declared excess to the needs of the depot maintenance activity, it will be returned to the supply system. The debit is to intra-DOD accounts receivable. If credit is granted, the debit is to cash. If credit is not granted, the accounts receivable will be reversed (credited) and charges will be processed as follows:

A. For material not identified to a specific job order, the material will be charged to the general and administrative expense account, "noncredit returns to the supply system."

B. For material identified to a specific job order, the charge will be to the "unallocated cost" deferred charge account until it is determined whether the non-use of the material resulted from a change in customer specifications or an over-buy on the part of the depot maintenance activity. If it is determined that the non-use is attributable to the customer, the cost will be charged to a separate job order for reimbursement by the customer but not to the job order covering the maintenance work done.

If it is determined that the depot maintenance activity is at fault, the cost will be charged to the general and administrative expense account, "noncredit returns to the supply system."

Reparable Exchange

When investment type assemblies, subassemblies, and components are designated as "exchangeables" an "average cost to repair" will be determined and catalogued. The average cost to repair is defined by work performance categories "A" and "I" and will be obtained from past experience in actually repairing the item or engineering estimates when no past experience is available. The average cost to repair should be updated annually. Previous cost experience should be modified for anticipated price level changes. The average cost to repair will be charged to the job order when the exchange takes place and is not dependent upon decisions to repair the items removed.

Missing Exchangeables

The standard catalog price or acquisition cost, if not a catalog item, will be charged to the job order for all missing "exchangeables" since an exchange cannot take place [60:310-330].

The costs associated with the following depot maintenance activities are also collected in HO36B according to the specifications of 7220.29H: purchased services, civilian and military travel (includes per diem and PCS), reclamation, calibration, modification, machine tool set-up time, defective work and spoilage, unutilized and underutilized plant, cancellation/reduction actions, training, technical assistance, manufacture, and depreciation. The data collected in the HO36B data system are stored on magnetic tapes which are updated quarterly. The data are also displayed on microfiche in a report

titled DOD Cost and Production Report. Most of the entries on the report are self explanatory; only a few need further explanation. The entry titled Serial Number is a sequential number assigned to each line entry in the report and has nothing to do with the equipment's actual serial number. The reporting facility entry is a numeric coding which corresponds with the entry under Facility Name (i.e. San Antonio, Oklahoma City, etc.). One important entry on the report is the Work Accounting code which explains why the maintenance was performed (e.g. code A - overhaul, code B - progressive maintenance, etc.). For a detailed explanation of these work performance categories refer to Appendix G. In Appendix G there are two sets of codes for work performance categories; one for categories used prior to 1 April 1977 and the other for categories assigned subsequent to this date. Very few publications presently have both sets of work performance categories (17).

To find the total cost for depot overhaul of a specific engine would require the tedious task of adding the data displayed on the HO36B output for civilian labor, military labor, direct material, maintenance contract services, general and administration, indirect, and contractor costs. This would have to be accomplished for each entry on the output with the specified engines item identity code. The average cost per engine could

then be calculated by dividing the total cost by the total number of engines overhauled (obtained by totaling the quantity completed for each entry). In order to more fully understand how this data is displayed, Figure 13, which is an actual reproduction of the 1976 HO36B data report, is provided. Using the first entry from Figure 13, serial number 0001013, as an example, the information in the following discussion can be extracted. The maintenance was performed at San Antonio Air Logistics Center. The items worked on were J-79-17 Turbojets. The work accounting code was A, which means that these engines received a zero-time overhaul (see Appendix G). The quantity completed was 81. The standard inventory price for this engine type was $163,505 (it is interesting to note that the price given in the HO36B data for this engine is identical to the price reflected in Table 14, Appendix F, for the J-79-17, which was the most current price which could be obtained for the Directorate of Propulsion, Headquarters, AFLC). Civilian labor hours worked were 117,144 for a cost of $892,045. Military labor hours worked were 103 for a cost of $650 (remember that this report was published prior to the DOD 7220.29H revision and that any data concerning military labor is incorrect). Direct material costs were $3,142,718. General and administrative costs were $23,456. Other indirect costs were $2,753. Adding all of these costs

Figure 13

DOD Cost and Production Report

SERIAL NBR	RPTG FAC	I/O US	OWN OPER	FACILITY NAME OR CODE	ITEM IDENTITY	ITEM NOMENCLATURE		WEA CODE	GRP CODE	WORK ACC	CUST CODE	QUANTITY COMPLETED	STD INV PRICE
CIVILIAN LABOR COST	HOURS		MILITARY LABOR COST	HOURS	DIRECT MATL COST STANDARD	OTHER	MAINT CONT SVCS	G A COST	OTHER IND COST			CONT COST-EX GFM&GFS	GOVT FURN GFM&GFS
0001013	5031	1	1	OKLAHOMA CITY	J7917	TURBOJET		1A-	A12	A	7F	0000081	000163505
000892045	0117144		00000043	0000010	03142718	00000000	00000000	00023456	00916042			000000000	00000000
0001014	5031	1	1	OKLAHOMA CITY	J7917	TURBOJET		1A-	A12	B	7F	0000001	000163505
000002242	0000295		00000005	0000001	00000000	00000000	00000000	00000052	00002753			000000000	00000000
0001015	5031	1	1	OKLAHOMA CITY	J7917	TURBOJET		1A-	A12	E	7F	0000000	000163505
000001440	0000187		00000000	0000000	00000000	00000000	00000000	00000041	00000946			000000000	00000000
0001016	5031	1	1	OKLAHOMA CITY	J7917	TURBOJET		1A-	A12	G	7F	0000002	000163505
000003765	0000441		00000000	0000000	00000000	00000000	00000000	00000075	00003756			000000000	00000000
0001017	5031	1	1	OKLAHOMA CITY	J7917	TURBOJET		1A-	A12	I	7F	0000004	000163505
000067384	0005850		00000000	0000000	00000000	00000000	00000000	00001946	00090902			000000000	00000000
0001018	5031	1	1	OKLAHOMA CITY	J7917	TURBOJET		1A-	A12	M	7F	0000001	000163505
000001792	0005850		00000000	0000000	00000000	00000000	00000000	00000063	00002126			000000000	00000000
0001019	5043	1	1	SAN ANTONIO	J7917	TURBOJET		1A-	A12	A	7F	0000123	000050000
001246593	0140286		00004194	0000605	04037574	00983619	00000000	00044796	01251478			000000000	00000000
0001020	5043	1	1	SAN ANTONIO	J7917	TURBOJET		1A-	A12	B	7F	0000006	000000000
000040177	0004304		00000336	0000046	00001295	00006744	00000000	00001183	00038571			000000000	00000000
0001021	5043	1	1	SAN ANTONIO	J7917	TURBOJET		1A-	A12	G	7F	0000003	000000000
000003726	0000445		00000000	0000000	00000000	00000000	00000000	00000138	00003447			000000000	00000000

together gives a total cost for this entry of $4,061,622. To find the total depot maintenance cost for the J-79-17 engine requires that the total cost of each entry in the HO36B data system for the J-79-17 be added together to arrive at a grand total. This type of mathematical manipulation while time consuming when done by hand, can be accomplished quite readily by a computer and HO36B will soon provide this capability.

The new HO36B data system, as amended by DOD 7220.29H, can be interrogated to obtain total cost or cost per unit for any engine overhauled at the depot level (17). This capability will greatly simplify the task of obtaining depot maintenance costs for an engine specified by Type-Model Series. Whether or not the old HO36B data will be reprogrammed to provide this capability is uncertain; the final decision will hinge on user requirements (17).

Personnel in AFLC Headquarters responsible for the HO36B data system believe that very few Air Force agencies use HO36B products (17). Many civilian companies request HO36B data (e.g. Lockheed, Grumman, Boeing, McDonald-Douglas, etc.) and at least one government organization uses the data; the Department of Commerce (17).

A detailed evaluation of the HO36B data system proves that it captures most, if not all, of the costs associated with depot maintenance (17). The system

accounts for all labor costs (with the exception that prior to revision by DOD 7220.29H military labor was not included), material costs (with the exception that prior to 1974 modification kits were excluded), other direct costs, and every conceivable type of overhead cost. The job order accounting system used to collect HO36B data permits assignment of all costs discussed above to each identifiable unit overhauled or repaired at the depot level. The data is collected in sufficient detail to allow determination of the total depot cost to support a specific Type-Model-Series engine and also the cost to overhaul or repair various subsystems of that engine (e.g. fuel control, compressor stages, etc.). In addition to this, use of the Work Accounting Code permits the user to determine the cost of performing a particular type of maintenance (i.e. overhaul, minor repairs, inspection, progressive maintenance, etc.).

The HO36B data since 1974 are reliable and valid, the system measures costs with consistent accuracy and assigns these costs to a properly identified unit. Prior to 1974, HO36B data are not considered of sufficient quality for analysis; primarily because modification kits were provided as a "free" good since they were not funded through the depot industrial fund. Additionally, military labor was not assigned as a cost element either. Since the DOD 7220.29H revision, no design limitations or

procedural problems were identified in the HO36B data system.

Component Improvement Program

The Component Improvement Program (CIP) is defined as:

> Those engineering services and related effort by the producing contractor or manufacturing installation applied to a propulsion system currently in production or the operational inventory for the purpose of extending its useful military life within the current performance envelope, integrating the engine into a campatible propulsion system, achieving specified system performance, reducing operational and/or manufacturing costs, increasing reliability and maintainability, and assuring an adequate manufacturing base. . . . Excluded is the effort directed toward increasing the performance beyond defined specification requirements [9:A-1].

CIP is nothing more than continued engineering support of an aircraft engine once the engine has been produced/ deployed (9:115). The 1976 PMR report stated that CIP was widely misunderstood and controversial but that it was necessary (9:113).

There are several reasons why a continuing engineering effort is required for aircraft engines. One reason is that aircraft engines are usually not fully mature in terms of RDT&E when they become operational (9:84). This is because jet engine development is the pacing item in a new weapon system, yet more often than not, the engine development is tied to the time constraints imposed by the airframe development. Another reason for CIP is

that some engines have design/material problems which may not be evident at first but after a few years of operation begin to cause operational problems (an example of this is the TF-41 engine in the A-7) (9:124). A third reason is that new knowledge and new techniques are constantly being made available for use in engines. CIP provides a method of getting this new knowledge into existing engines (9:114).

CIP funding. CIP is a large program, in fact, for some engines more money has been spent on CIP than it took to buy the engine in the first place (3). Table 9 contains the annual CIP funding for 6 engines. As can be seen, the recommended funding for CIP for just these 6 engines came to over $110 million in 1974. The total CIP recommended throughout the life cycle of the J-79 engine used in the F-4 aircraft is just over $410 million. There is one important point to remember about CIP funds. CIP prior to 1969 could be used to improve the performance specifications of the engines. Many new dash models of engines were produced by CIP (9:122). But in 1968, Congress stopped the use of CIP for improvements in specifications (3). Therefore, it is impossible to determine how much CIP prior to 1969 was used for improved supportability which is a true support cost, and how much was used to improve performance, which is not a true support cost.

Table 9

Annual CIP Funding Recommendations
$ in Millions (9:123)

Year	J79	TF41	TF30	TF39	TF34	F100
1956	75.50					
1957	62.00					
1958	69.00					
1959	38.70					
1960	22.10					
1961	14.70		16.80			
1962	7.50		21.50			
1963	15.65		43.00			
1964	15.00		47.50			
1965	16.00		47.00			
1966	12.00		55.30			
1967	10.00		35.00			
1968	10.42	1.20	34.50	6.27		
1969	8.50	8.00	34.00	19.20		
1970	8.00	13.50	32.00	18.40		
1971	6.80	14.50	23.00	16.50		
1972	6.79	11.00	25.00	23.00	1.50	
1973	3.40	9.90	21.20	14.40	12.00	23.50
1974	5.12	12.86	13.78	11.00	6.00	61.70
1975	3.83	10.20				

CIP funds come from four sources: the Air Force, other services, foreign users and the engine contractors. Funds come from the other services and foreign users when the CIP will benefit them (such as in the case of the J-79 engine which is used by the Air Force, Navy and many foreign countries) and from commercial sources when the CIP can be applied to a civilian engine (9:120-122). In the Air Force, funds come from AFSC or AFLC. Money spent by AFSC is ususally to correct some operational problem or parts life while AFLC money is usually spent to improve repair procedures or parts life (9:303).

There is at the present time no data system which contains all of the CIP data. However, one organization is constructing a data base which will contain CIP data from all sources for all engines ever since the CIP program began (5). This office is the Products Improvement Office (YZI), Deputy for Propulsion, Aerospace Systems Division, AFSC, here at Wright-Patterson AFB. This data system will be in operation in July 1977 and data will be stored on the AFLC CREATE computer (5). Persons having a need for the data will be able to obtain hard copies from YZI. Figure 14 is a sample of what format the data is in. This data can be obtained by calendar year, fiscal year, and in constant dollars for whatever base year the user wants to use.

Figure 14

Sample CIP Output (5)

Engine Product Support Program Dollars
T56-G-10A/12A
(Thousands of Dollars)

Year	AFSC	AFLC	Navy	Indirect	Contr	Total
71	0	740.4	740.4	0	349.2	1830
72	0	600	600	0	270.0	1470
73	0	475	544.6	0	239.4	1259
74	UNABLE TO FIND DATA					
Total	0	1815.4	1885.0	0	856.6	4559

In evaluating this data base the first important point is that the data base is being established specifically to collect CIP costs. A second point is that every effort is being made to collect complete CIP data which, if successful, will be the first time this has been accomplished. Another important point is that the data will be in sufficient detail to enable the user to analyze how much CIP money from each source has been spent on any engine. Finally, there are no design or procedural problems with the data base which are anticipated to reduce the overall quality of the CIP data.

Aerospace Ground Equipment

Aerospace Ground Equipment (AGE) is defined as being:

> All equipment required on the ground to make a weapon system, command and control system, support system, advanced objective, sub-system, or end item of equipment operational in its intended environment.

> This includes all equipment required to install, launch, arrest, guide, control, inspect, direct, test, adjust, calibrate, gage, measure, assemble, disassemble, handle, transport, safeguard, store, actuate, service, repair, overhaul, maintain, or operate the system. . . . [16:20].

This definition is limited to that AGE which is used for jet engines at the operating location.

There are several methods of estimating AGE costs. In one report, the AGE costs for one base supporting T-38 aircraft were determined then this amount was multiplied by the number of bases where the T-38 is located and the resultant amount was the AGE costs for the T-38 aircraft (9:J-10). There are two reasons why this method is not recommended:

1. This research is directed at engine AGE costs, not total aircraft costs.

2. The resultant figure is too gross, too much of an approximation for one to have much degree of confidence in it's accuracy.

Another method of measuring AGE costs would be to examine the actual engine AGE costs for all nine of the bases where the T-38 aircraft are located. This method, while being more accurate, would be very time consuming.

There is a much easier method of estimating these AGE costs. This method utilizes Tables of Allowance (TA's) which establish what equipment is authorized for use by what unit (24). At the Support Equipment Branch [illegible], DCS Logistics Operations, Headquarters AFLC, all TA's [illegible]

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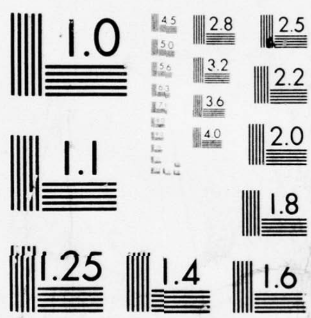


MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

all support equipment in the Air Force are kept on microfiche and computer tape.

The Tables of Allowance are the means by which the Air Force manages the issuance of all equipment items (24). Although the TA's are not designed for cost estimation, there are three characteristics of the TA's which make it possible to determine AGE costs for jet engines:

1. The TA's are organized so that the equipment required for the jet engine shop is located in TA-760, Aircraft Engine and Accessory Tools and Equipment.

2. This TA is further organized into jet engine type, i.e., J-57, J-75, J-79, &-85, etc.

3. The unit prices of all equipment used by the Air Force are contained by national stock number (NSN), in TA-001, Master Equipment Management Index.

In order to estimate AGE costs for a particular engine, one would refer to TA-760, Aircraft Engine and Accessory Tools and Equipment. For example, Part D Section C contains the test stands and auxilary equipment for the J-79 engine (Figure 18, located in Appendix D, is a portion of the table of contents of TA-760 for test stands and auxilary equipment). If one could turn to Part D Section C one would find the Organizational Item List (an example of the Organizational Item List is found in Appendix D, Figure 19). This item list catalogues the AGE by national stock number (NSN), nomenclature and part

number. On the right hand side is the basis of issue for the piece of equipment. The first row of letters represents the engine application. The second row of numbers preceded by the letter A are for organizational level maintenance and numbers preceded by the letter B are for intermediate level maintenance. Referencing Figure again, for the adapter life-front/rear compressor stator assembly, NSN 1730-00-202-8700, this piece of AGE applies to the J-79-GE-3B, J-79-GE-7A, J-79-GE-15, J-79-GE-17. It is not authorized for the organizational level but there is one of these for every 72 installed engines at the intermediate maintenance level. To find the total amount of AGE required for the J-79 engine, one would have to sum all the items listed in the TA-760 which apply to the J-79.

Once one has listed the AGE required, he would then have to determine the cost for this AGE. Fortunately TA-001, Master Equipment Management Index lists the cost of all equipment in the Air Force by NSN (24). Figure 20 located in Appendix D, is a sample from this Master Index. In the previous example, for the adapter life-front/rear compressor stator assembly, NSN 1730-00-203-8700, the unit cost is 90.13 and it is issued in 1 each units. By crossing all of the AGE found in TA-760 with the prices in TA-001, one could find the cost for AGE for a particular jet engine. The problem with this method is that

there are may be as many as 600 to 800 pieces of AGE for a particular engine, and no one would have the time to do the amount of research required to cross reference that amount of equipment from one TA to another (24). There is a simple solution to this problem. These TA's are also on computer tape with the AFLC CREATE computer. If a user had the need to know the cost of the AGE for a particular engine, it would be possible to have the computer do the research and cross referencing work (24). The user would have to coordinate his requirements with LOWCT and expect at least a two week wait for the products (24).

In evaluating the usefulness of this data base as a source of AGE costs, one must address the accuracy of the results. As was pointed out earlier, the TA's contain the authorized amount of equipment, not the actual amount on hand. In spite of this, the difference between the authorized amounts of AGE and that amount which is on hand is probably small (24). One cost which is not captured by this technique is the cost of operating and supporting the AGE equipment. The support of support equipment was not included as a portion of the O&S costs of an aircraft engine so this is consistent with other data sources described. A major inconvenience of using these data sources is the computational effort required but the use of the computer has eliminated much of this effort.

Fuel and Oil Costs

Fuel and oil costs must be identified separately and not lumped into some aggregate engine operating and maintenance cost at a base (29:183). These costs comprise a significant portion of an engines total operating and support costs and are dependent upon the designed performance parameters of the engine. Fuel and oil costs for an engine are also highly dependent upon the mission profile and operational use of the weapon system it is installed in (29:183). The USAF Cost and Planning Factors, AFR 173-10, is one source which can be used to estimate the fuel and oil costs of an engine (20).

Cost and planning factors. This regulation provides cost and planning factors for use in estimating and analyzing resource requirements and costs for the USAF (51:i).

> Within both the Air Force and the Department of Defense (DOD), cost and planning factors are playing an increasingly important role in the planning, programming, budgeting, and decision-making processes. The Air Force has been a leader within DOD in the development, validation, and productive use of such factors. Factor and estimating technique development is an evolutionary, dynamic process. The factor which served its purpose so well yesterday may not represent the best solution for satisfying today's requirement. A number based on this year's budget requirements may not be the best number to use in a planning study looking years ahead or a life cycle cost study. As new data sources become available, or estimating techniques are improved, or insight gained or needs for or uses of data, cost and planning factors, estimating techniques, or models must be changed [51:Forward].

AFR 173-10 is published in three volumes: Volume

I is unclassified; Volume II is classified Confidential as it contains strength and operational information; Volume III contains aircrew composition for active forces aircraft with special missions and is classified Secret (51:1-1). Aviation fuel and oil cost factors are contained in Volume I. Table 10 is a partial listing of the Aircraft Fuel Consumption and Cost Factors, Table 3, from AFR 173-10. The following explanation of this table was extracted from the regulation:

> Aircraft Fuel Consumption and Cost Factors:
>
> a. Purpose. To provide aircraft fuel consumption and cost factors for use in estimating fuel and oil requirements or costs, flying hour costs, and for establishing reimbursement rates.
>
> b. General:
>
> (1) Gallons of Fuel Per Flying Hour. Computed by dividing the number of net gallons of fuel reported issued worldwide to aircraft from 1970-1974 by the number of flying hours reported for such aircraft during the same period. Form 15 and Into-Plane purchases are included. Data on fuel issued to Air Force aircraft are derived from the RCS: HAF-ACM(SA) 7111 report prepared by SAAMA/ACDCF. Data on Air Force flying hours are derived from the RCS: HAF-LGM(AR) 7101 report prepared by AFDSC/GLLP.
>
> (2) Fuel Cost Per Flying Hour. Computed by multiplying the gallons of fuel used per flying hour by the cost of JP-4 or aviation gas (Table 4) as appropriate for the type of aircraft.
>
> (3) Cost of Oil. Computed by multiplying the gallons of fuel per flying hour by the cost of oil estimated consumed per hour (Table 4).
>
> (4) Conversion. Quantities of fuel can be converted from gallons to barrels dividing the number of gallons by 42.

Table 10

Worldwide Aircraft Fuel Consumption and Cost-Per-Flying-Hour-Factors

Bomber Aircraft M/D/S	Engine Type & Model	Grade of Fuel	Gals of Fuel Per Flying Hr.	Fuel Cost Per Flying Hr.	Type of Oil	Oil Cost Per Flying Hr.	Total Fuel & Oil Cos Per Flying Hr
T-38	J85-6E-5	JP4	385	136	Syn Jet	.30	136
B-52H	TF33-3	JP4	3375	1188	Syn Jet	2.55	1191
FB-111	TF30-7	JP4	1390	489	Syn Jet	1.05	490
F-105G	J75-P-19W	JP4	1325	466	Syn Jet	1.00	467
F-4E	J79-6E-17	JP4	1500	528	Syn Jet	1.15	529
A-7D	TF41-A-1	JP4	670	236	Syn Jet	.50	237
C-5A	TF39-6E-1	JP4	3435	1209	Syn Jet	2.60	1212
C-141	TF33-P	JP4	2160	760	Syn Jet	1.65	762
KC-135Q	J57-59W	JP4	2405	847	Syn Jet	1.85	849

> Fuel may be converted to pounds by multiplying the number of gallons at 60 degrees F by 6.4 for JP-4 and by 6.0 for 115/145 aviation gas [51:2-2].

To calculate the fuel and oil costs for an F-4E for example, the following data would be extracted from Table 10. Fuel consumption per flying hour, 1500 gallons. Fuel cost per flying hour, $528. Oil cost per flying hour, $1.15. Total fuel and oil cost per flying hour, $529. Using these fuel and oil costs per flying hour, one could easily determine fuel and oil costs for support of a specific aircraft if the hours flown were known.

Changes to AFR 173-10, Table 3 are issued whenever bulk fuel costs for either jet fuel or aviation gasoline are changed by $0.001 per gallon (51:2-2). This sensitivity is necessary to maintain the accuracy of the fuel and oil cost factors with todays volatile petroleum prices.

There are other cost and planning factors in AFR 173-10 which can be useful in forecasting operating and support costs (e.g. aircraft depot maintenance cost factors, base-level aircraft maintenance factors cost per flying hour, replacement common aerospace ground equipment and spares cost, etc.) Table 11 is a partial listing of the Aircraft Depot Maintenance Cost Factors Table from AFR 173-10. To estimate the annual depot maintenance cost for a single F-4E aircraft with a programmed utilization rate of 300 flying hours per year, use the factors from Table 11 and the following equation

extracted from AFR 173-10:

$$DM = QA + QBX$$

Where DM = Depot Maintenance Cost Per Aircraft Per Unit Evaluated (UE) Per Year

Q = Number of aircraft/UE

A = Annualized aircraft/UE cost factor

B = Flying Hour related cost factor

X = Number of Flying Hours per year [51:A-16].

Solution for the F-4E example:

$$\begin{aligned} DM &= (1)\ (\$65{,}098) + (1)\ (\$154)\ (300) \\ &= \$65{,}098 + \$46{,}200 \\ &= \$111{,}298 \end{aligned}$$

[51:A-16].

Table 11

Aircraft Depot Maintenance
Cost Factors (51:A-15)

Aircraft M/D/S	Annual Cost Per Aircraft	Annual Cost Per UE	Cost Per Fly Hr
F-4E	$ 65,098	$ 71,608	$154
T-38	5,962	6,558	42
B-52H	233,090	256,400	455
C-141	126,565	139,222	92
A-7	30,316	33,347	165

The depot maintenance cost factors were developed using Headquarters AFLC cost data for FY 1969 through 1973 with Headquarters USAF/LGY data "on the estimated allocation of maintenance hours within the organic maintenance, interservice maintenance, and contract maintenance areas consideration [51:2-3]." These factors were developed using the variable costs of depot maintenance, fixed costs were not included (51:2-3).

An evaluation of AFR 173-10 produced mixed findings. The cost and planning factors for fuel and oil are reliable since they are changed promptly in response to very small price changes and all factors in the regulation "are under continuous review, development, and improvement [51:2-1]." Appropriate changes are published as required or at least annually (51:1-1). The factors in AFR 173-10 are valid; predicated on the fact that the correct factors are used with the limitations specified in the regulation. The detail of the Cost and Planning Factors is by design very broad and general. The factors are designed to be used in general estimates and are not detailed lower than the weapon system level. In other words, estimates can only be made for entire weapon systems, not for subsystems or components of the total system (e.g. engines, accessories, etc.). Also, the factors sometimes exclude important cost elements (such as the fixed costs of depot maintenance discussed earlier).

Engine Status Reporting

> "The basic objective of the engine reporting system is to obtain accurate current information on status, condition, and location of all aircraft engines in the Air Force inventory [44:1-11]."

AFM 400-1 details the various aspects of engine management and DO24, "Propulsion Unit Logistics System", furnishes the management information required to make decisions concerning engine management (44:1-1). The intermediate

objectives of the 400-1 system are to maintain an accurate and timely engine inventory, reduce pipeline times, speed transportation, reduce overhaul time, extend field maintenance capabilities, and streamline engine management techniques (44:1-1).

The following list provides a brief explanation of various engine transaction, condition, and status changes that are reported in the 400-1 system for both installed and uninstalled engines:

<u>Receipt</u>. Report all engines physically received at a base or depot, including engines removed from transient aircraft and those received/transferred from classified projects (L account). A receipt report submitted for a module engine will cause the ADP equipment at Oklahoma City ALC to automatically generate receipt reports for the installed modules. The receipt of an uninstalled module will be reported in the same manner as an uninstalled engine.

<u>Shipment</u>. Report all uninstalled and uninstalled nonflown (an engine installed in an end item that is moved through the transportation system) engines shipped off base to another installation. An exception is an engine being prepositioned at another station in support of the home base. A shipment report for a module engine will cause the ADP equipment at Oklahoma City ALC to automatically generate shipment reports for the installed modules. The shipment of an uninstalled module will be reported in the same manner as an uninstalled engine.

<u>Start Work</u>. The beginning of work on an engine or module requiring maintenance modification, buildup or resumption of work following work stoppage.

<u>Removal</u>. The removal of an engine from an end piece of equipment for any reason. For module engines, report removal of the module engine from the end item and the removal of the module from the engine. Codes used to depict reason for removal are contained in AFM 300-4, ADE EN-278-III.

Installation. The installation of an engine in an end piece of equipment. For module engines, report installation of the assembled engine in the end item. For modules report installation of the module in the engine. The ADP equipment at Oklahoma City ALC will not accept an installation report for a module engine unless it has record of installation reports for each of the modules that make up the engine. Modules will never be reported as installed in the aircraft.

Completion of Work. Completion of maintenance, modification, or buildup of an engine or module. This also includes completion of work resulting in a change of engine designation.

Status Changes. Status changes include changes in condition, command code, organization code or other reports that update the centralized account. All changes in transaction or condition of engines and modules must be reported.

Change in Maintenance. Any change in the level of repair (for example, from major overhaul to minor overhaul).

Loss. Any engine or module lost from the Propulsion Unit Reporting System.

Gain. Any engine or module gained to the Propulsion Unit Reporting System. This includes engines received from other agencies for repair and return On module engines, submit one report on the complete engine and one report on each module.

Periodic Inspection and/or Reconditioning Cycle. All engines or modules removed for periodic Inspection/Reconditioning Cycle will be reported with a reason for removal code of 8Q. An engine removed for this purpose must be reported in a reparable condition. The removal of a module engine for periodic inspection and/or reconditioning cycle must be followed by the removal of the individual modules. Upon completion of the inspection/reconditioning cycle the module or engine will be reported under transaction work completed, condition serviceable buildup.

Account Transfer. Transfer of an engine or module from the Air Force account to a non-Air Force account or from a non-Air Force to an Air Force account.

Work Stoppage (ENORS). Any engine or module in uninstalled status that required parts from depot supply before work can be started or resumed to accomplish repair or buildup. The module engine is in work stoppage ENORS when a module is not available and work cannot be continued to assemble the engine. This term also described an engine or module in overhaul that is in work stoppage due to depot supply parts shortage.

Work Stoppage (Other Than Parts). When an engine or module has been reported in an ENORS or work started status and a work stoppage occurs for lack of manpower, tools, workspace or parts in repair cycle processing (DIFM) where a valid ENORS condition does not exist, a work stopped status must be reported.

Test Cell Reject. An engine or module removed from test cell for performance of additional maintenance to correct malfunction detected during test cell check.

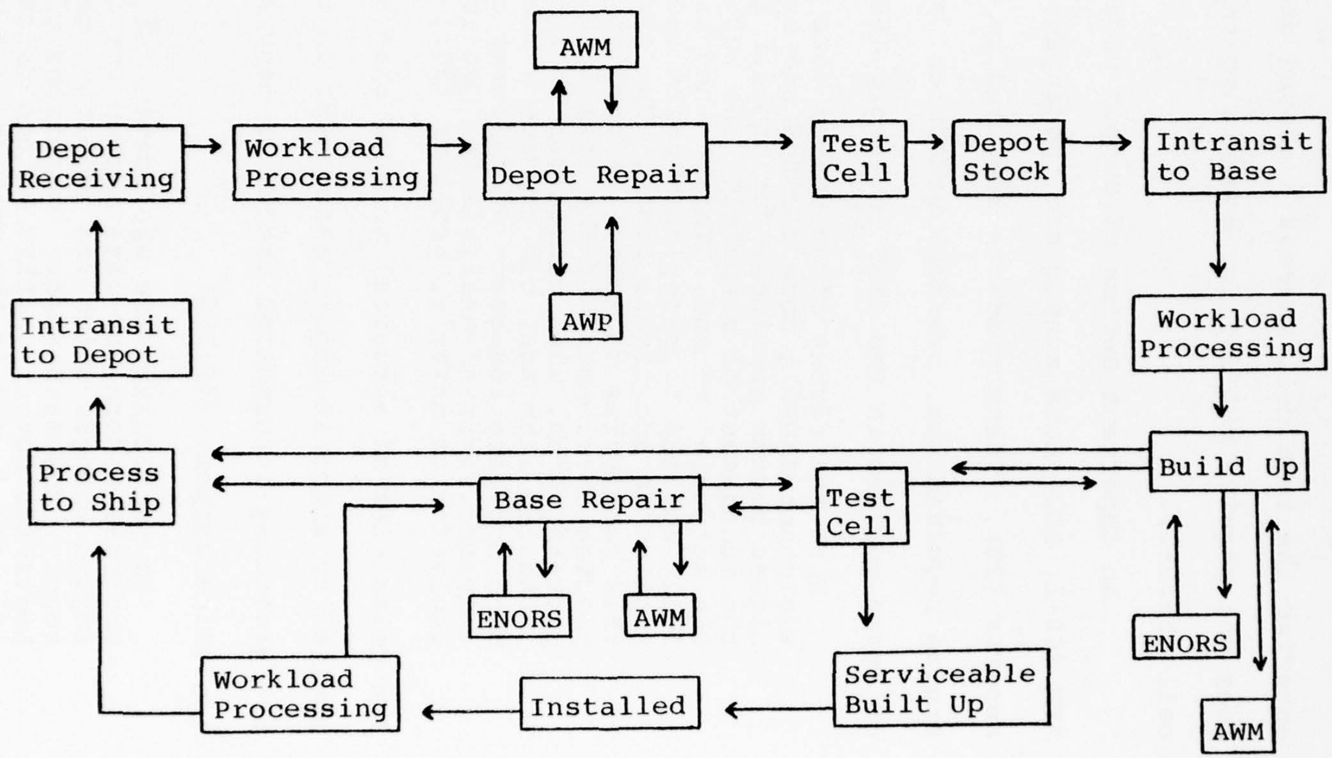
Transfer (Flown). Installed aircraft and Auxiliary Power Unit (APU) engines flown to another station for assignment to the recipient. For module engines, submit one report on the complete module engine and the ADP program will automatically generate shipment/transfer reports on the installed modules.

Engine Checks (Other Than Periodic Inspection). Engine checks performed as a part of the end piece of equipment phased inspections will not be considered or reported as engine periodic inspections. Additionally, maintenance performed in accordance with Aircraft-2 Maintenance Manuals will be considered as organizational maintenance and reported on AFTO Form 349, Maintenance Daily Collection Record. Maintenance performed in accordance with T.O. 00-20-2-4, "Off-Equipment/In-Shop," must be submitted on an AF 1534 as required by para 3-4 above [44:3-1, 3-2].

Figure 14 is a diagram of the status and conditions that an engine may pass through during the 400-1 reporting process. Every engine in the inventory may not follow the exact path indicated in this figure; the flow depicted is a logical flow for a typical engine. An exception for example, would be a ground gas turbine engine as

Figure 15

Engine Flow Logical Reporting Diagram (56:9-2)



opposed to a jet engine; a jet engine shipped to a base from the depot must go into a buildup status prior to entering the test cell whereas a ground gas turbine engine does not require buildup nor does it go through the test cell (56:9-2).

An important series of output products from the AFM 400-1, DO24 data system are the engine actuarial data reports (20). These products are used to determine spare engine requirements, overhaul schedules, and distribution of spare engines in the USAF inventory (56:9-2).

> With the advent of automated data processing equipment (ADPE), more refined and exacting techniques become available for broader application in the management of materiel. One such technique is the actuarial method. This method has been successfully applied to propulsion units and can now be applied to additional items. The significance of this particular technique is that it permits a more precise development of the item life and its failure pattern which, when considered in relation to the installed item age, can provide a means of performing more accurate forecasts of failures and more detailed comparative trend analysis for determination and isolation of materiel problems [56:1-1].

The principles of actuarial science that are now being applied to aircraft engine management in the Air Force are providing information useful in many aspects of logistics support (49:2-2).

> In particular, the application of these principles produces a more accurate method for determining engine changes which are important to the procurement, supply, and maintenance operations of Air Force Logistics Command. This method is called the actuarial method, and is the same as that used by life insurance institutions to calculate human mortality rates and life expectancy. The use of the method has

its basis and justification in the fact that aircraft engines are in many respects similar to human beings. A human being is physically a collection of many parts working together, one or more of which may fail at any time and cause death or the need for medical care. In the same way an engine is a collection of many interrelated parts working in a coordinated manner, one or more of which is subject to failure at any time, causing the engine to be "junked" or to require overhaul. This complex, simultaneous functioning of many parts (as well as several other important factors) brings to light one of the most important single principles of actuarial sciences: as a human being changes age, i.e., grows older, he is subject to constantly changing yearly death rates. In other words, the probability of death (or failure) is dependent on, or is a function of age. The applicability of the actuarial method to the mortality of people or to failures of any item of equipment is dependent on this principle. For those items of equipment whose failure pattern or probability of failure is independent of age, ordinary statistical methods are more applicable and desirable. It has been proved that the above principle does hold true with aircraft engines. For engines the use of the actuarial method has greatly improved the accuracy of forecasts, estimates, and planning factors, resulting in significant savings to the Air Force. The actuarial method accomplishes two major objectives: it gives us a set of failure rates which vary by age, and it uses these rates to make accurate engine removal forecasts. [49:2-2].

The actuarial ADP products for aircraft and gas turbine auxiliary engines are processed in the AFM 400-1, DO24 data system under two separate programs; DO24F (subsystem of propulsion unit logistics systems actuarial computations) and DO24K (subsystem of propulsion unit logistics system actuarial computations forecast products) (56:8-1). The DO24K products display the actuarial forecasts which are used by engine management activities (56:8-1). The actuarial product most widely distributed in the Air Force is DO24KPO6-K, Official USAF Actuarial

Removal Interval and Engine Life Expectancy Tables (20).

DO24KPO6-K. This product is published quarterly and is used primarily by:

> HQ AFLC - to compute spare engine requirements.
> Major Commands - to establish engine stockage objectives.
> Engine Inventory Managers (ALC's) - to compute overhaul requirements and retention quantities.
> MAAGS and MISSIONS - to compute spare engines and overhaul requirements [55:1].

Table 12 is an example of an actuarial engine removal table. RR is the planned rate of return to service for engines receiving base repair. OHRI LMT is the overhaul removals interval excluding maximum time removals. OHRI WMT is the overhaul removals interval including maximum time removals. BMRI is the base maintenance removal interval. CMRI LMT is the combined removal interval (overhaul plus field maintenance removals) including maximum time removals. Each removal interval on the DO24KPO6-K report is the ratio of the projected engine operating hours per removal.

> The engine operating hours are computed for each TMS based on the HQ USAF PA document. Removals are computed by means of a simulation model composed of inputs derived from AF Form 1534 reporting [55:i].

To compute the number of removals for a given engine in a given quarter, engine operating hours for the required quarter must first be computed in the following manner (55:ii):

Table 12

Official USAF Actuarial Removal Interval Table
Engine/Aircraft J79-GE-15/F-4C,D

FY	QTR	TIME	DI	RR	OHRI LMT	OHRI WMT	BMRI	CMRI LMT	CMRI WMT
77	2	1200	1.00	0.86	3334	1019	543	467	354
77	3	1200	1.00	0.86	3401	1096	554	476	368
77	3	1200	1.00	0.86	3407	1054	555	477	363
FY TOTAL					3381	1056	550	473	362
78	1	1200	1.00	0.86	3409	1011	555	477	358
78	2	1200	1.00	0.86	3441	1036	560	482	364
78	3	1200	1.00	0.86	3446	1091	561	482	370
78	4	1200	1.00	0.86	3494	1059	569	489	370
FY TOTAL					3448	1049	561	483	366
79	1	1200	1.00	0.86	3470	1060	565	486	369
79	2	1200	1.00	0.86	3349	1115	545	469	366
79	3	1200	1.00	0.86	3319	1258	540	465	378
79	4	1200	1.00	0.86	3243	1442	528	454	386
FY TOTAL					3344	1200	544	468	375

$OT = FH_{A/C} \cdot QPA$

Where: QT = Operating time of the engine for a quarter

$FH_{A/C}$ = Flying hours projected for the aircraft using the engines

QPA = Quantity per application, the number of engines per aircraft [55:ii].

To find the expected quantity of removals for a given quarter, divide the flying hours by the selected removal interval obtained from the actuarial removal table. For example, if one wanted to forecast the total expected removals (for all types of maintenance) for an F-4C Squadron projected to fly 500 hours in the fourth quarter of FY 77, the following computations would be made:

$$OT = FH_{A/C} \cdot QPA$$

$$= 500 \cdot 2 \text{ (engines per F-4C)}$$

$$= 1000$$

Expected removals = OT ÷ CMRT WMT (obtained from Table 12)

= 1000 ÷ 363

= 2.75

Once the expected quantity of removals has been calculated, spare engine requirements can be estimated by utilizing a rather complicated mathematical model. Basically, the model uses a Poisson distribution to estimate failure rates and couples these rates with known maintenance times (including removal, transportation, depot and base repair, and installation), required flying hours, and number of aircraft available, to arrive at an estimated spare engine requirement (20).

The AFM 400-1 data system is an extremely reliable and complete system. It functions primarily as a Management Information System and provides all the data necessary to manage the large Air Force inventory of over 39,000 engines (see Table 3). The 400-1 data system closely monitors and reports on the location and operational status of every engine in the inventory. The system is highly detailed and very structured for the purpose of engine status reporting. It does not, as a function of design, collect engine operation and support costs.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Overview

The organization of this chapter will be as follows: conclusions directly associated with findings and results will be presented first, followed by corollary conclusions. A summary of assumptions and limitations will be presented next. Recommendations for further study are proposed and then a brief summary of the study.

Conclusions

The following conclusions are general in nature and apply to all data bases in this study.

1. The data bases which presently exist in AFLC are, for the most part, not designed to collect operation and support cost data. In most cases, the data systems collect O&S costs almost as an afterthought. The data bases which do collect O&S cost data are fragmented and greatly diverse in format and terminology. All of the cost elements (e.g. depot maintenance, base maintenance, CIP, etc.) necessary to operate and support a specific weapon system (e.g. F-4, C-5, T-38, etc.) or an integral component of a weapon system (e.g. engines, airframe,

accessories, etc.) are not collated or compiled in one data system. Rather, as done in this study, numerous data bases must be interrogated separately and the independent results added together to arrive at a total cost to operate and support a weapon system or weapon system component.

2. Data bases which collect O&S cost data are not well integrated; there is little or no interaction between designers and/or users of the various data systems. For example, the IROS system and the HO36B system both collect depot maintenance costs, and yet each uses a different data source. Interaction between the organization responsible for each system could reduce duplication of effort.

3. Data bases at Headquarters, Air Force Logistics Command should be integrated into one data base, using the best data sources for each type of cost. This conclusion is supported by the problems that the IROS data has with inaccurate not reparable this station (NRTS) rates. The IROS depot repair costs are keyed to a NRTS rate which is not accurate, and the people who manage the IROS data know where more accurate NRTS data exists (the 400-1 actuarial data, DO24 system) yet the inaccurate IROS NRTS rates are still being used. It would improve the IROS data if the NRTS rates from the DO24 actuarial system were incorporated into the IROS data system. Even better than this system, which calls for the number

of items which are NRTS multiplied by the depot standard repair rate to obtain the depot repair cost, one could simply replace it with the HO36B, DOD Cost and Production report. The HO36B system is a very accurate system for actual (not computed) depot repair costs. This is the most accurate depot cost system in the Air Force, yet it would appear that no one in the Air Force uses it. The ideal situation would be for AFLC to coordinate and integrate these systems into one master data base and then discard the more inaccurate systems. Then if a user had a need to know cost, usage or actuarial data for a weapon system, he would simply query the same master data base.

The following conclusions are of a more specific nature concerning the data bases which were described in the study.

1. The IROS data system generates depot repair costs which are not the most accurate that the Air Force has.

2. The IROS data system contains base repair costs which are not as accurate as they could be, but this is caused by reporting problems with the 66-1 data more than any inherent design problems with IROS. Since any system of collecting base level maintenance costs is dependent upon the quality of 66-1 data, the IROS data is as good as anything else in the Air Force.

3. Starting in Fy 1978, the HO36B data system will provide depot maintenance cost data that AFLC personnel believe will be incredibly accurate and comprehensive (17). Data from the HO36B system collected prior to FY 1978 has two major weaknesses; it does not include military labor costs nor does it collect the costs of modification kits consumed at the depot level. These two problems have been corrected, and the HO36B data system is now vastly superior to the IROS system in the area of depot maintenance cost collection.

4. The Component Improvement Program data base is suitable for use in estimating past CIP expenditures. It is complete and detailed.

5. The method employed for estimating Aerospace Ground Equipment costs is acceptable. It is used in the place of a true cost data base because a true cost data base for AGE does not exist in AFLC.

6. The cost and planning factors from AFR 173-10 are not acceptable for use in forecasting depot and base maintenance costs for jet engines since they are applicable only to entire weapon systems. AFR 173-10 can be used quite readily and accurately for the estimation of fuel and oil costs.

7. The engine status reporting system, DO24, as prescribed in AFM 400-1, is useful in the determination of spare engine requirements. The costs of spare engines

can be considered as an operation and support cost or an acquisition cost; the actuarial data from the 400-1 data system can be used to help estimate these costs. It is interesting to note that this data base, which is designed to help determine maintenance requirements and spare levels to support the operational mission, is better developed and more accurate than data bases which collect cost data (for example, the IROS system).

Corollary Conclusions

Corollary conclusions are those conclusions which are not directly supportable by the findings, yet are discovered during research and add value and credibility to the original thrust of the study.

1. There is much activity in the life cycle cost estimation area, yet there is little integration and no central theme to this activity. In the course of this research, at least four separate groups of individuals were identified who were attempting to estimate life cycle costs of systems, with no knowledge of the efforts or experiences of the other groups.

2. All of the data bases in AFLC are based upon recording utilized labor hours as being the labor cost of supporting a system, yet the Air Force is paying for available labor (that labor actually used plus that which, for various reasons, is not used). The true cost of labor can be best determined by accounting for all of

the labor available.

3. Cost models should be formulated to fit the existing O&S cost data. It would appear that models are formulated and then an attempt is made to find existing data which fits the model. This causes many problems in the validation and use of a model.

Summary of Assumptions

The following assumptions were made in this study:

1. Adequate O&S cost data existed at Headquarters, Air Force Logistics Command to estimate the O&S costs of a jet engine.

2. Adequate information in the form of expert opinion and past studies on life cycle cost exist to evaluate data bases involved with O&S costs.

3. The portion of O&S costs for jet engines made up of maintenance costs, Component Improvement Program costs, fuel and oil costs, Aerospace Ground Equipment costs, and spare engine costs is the major portion of jet engine O&S costs.

4. The breakdown utilized for types of O&S costs is the one that most clearly correlates with the breakdown of O&S costs in Air Force data systems.

5. The data sources which were described were appropriate for use in cost estimation.

Summary of Limitations

The following limitations were identified in this study:

1. The data base search was limited to Headquarters, AFLC.

2. Only data bases containing O&S cost data for turbojet and turbofan engines were considered.

3. No attempt was made to actually determine the O&S costs for a particular engine.

4. The discussion and description of the data bases were limited to that portion of the data bases which contained O&S cost data or data which could be used to estimate O&S costs.

Recommendations for Further Research

There are three specific recommendations for further research.

1. The first is related to the observation that the whole area of O&S cost data collection and reporting is in a state of change. Therefore a follow-on study could be made to evaluate these changes as well as report on new data bases.

2. The second recommendation is that a research effort be made to actually estimate O&S costs for a specific jet engine using these data bases.

3. The third recommendation is that an effort be made to formulate an O&S cost model designed to utilize

existing O&S cost data

Summary

This research study was made to investigate what data bases are currently available to estimate O&S costs and to describe and evaluate these data bases. This study demonstrated that some good O&S cost data bases exist, but that much work is required before O&S cost accounting in the Air Force will be at an acceptable level both in terms of quantity and quality.

APPENDIXES

APPENDIX A

AIRCRAFT ENGINE LIFE CYCLE COST METHODS IMPROVEMENT WORKING GROUP MODEL

Models are tools which provide a simplified representation of a real situation and can vary from a simple mathematical equation to complex computer programs with hundreds of variables (28:15). The purpose of this appendix is not to fully describe the theory behind models but to give readers with a limited mathematical background an understanding of how the Working Group Model functions.

Working Group Model. The Working Group Model is an accounting model i.e., the individual cost elements are first quantified and then summed to give the life cycle costs (28:16-17). This model was specifically developed for use during source selection (57:1). The cost produced by the model, which is not an absolute program cost but a figure of merit from which comparison can be made, is derived from summing 53 separate equations. These equations appear in Table 13 (57:Atch 2) where the letters R, A, and S mean research and development, acquisition and support respectively.

These equations describe the major cost elements of the life cycle cost of a system. Each equation may have many sub-equations. A thorough presentation of all of these sub-equations is not warranted here since in this effort the model is used for cost element identifi-

Table 13

Equation Index (23: Attach 2)

TITLE	R	A	S
Conceptual Study, Cycle and Configuration Cost	1		
Mockup Cost	2		
Detailed Engine Design Cost	3		10
Tooling Cost	4	2	
Engine Manufacturing Cost	5	3	11
Cost of Engine Spare Sections	6	4	
Peculiar Aerospace Ground Equipment Cost	7	5	12
Common AGE Cost	8	6	
Special Test Equipment Cost	9	7	13
Packaging and Shipping Cost	10	8	8
Facilities Cost	11	9	
Contractor Test Cost	12		14
Government Testing Cost	13		15
Training Cost	14	10	1
Contractor Field Support Cost	15	11	2
Data Cost	16	12	3
Initial Inventory Management Cost	17	13	
Recurring Inventory Management Cost	18		4
Engine Scheduled Maintenance Cost	19		6
Engine Unscheduled Maintenance Cost	20		7
Recurring Maintenance Management Data Cost	21		5
System Engineering/Project Management Cost	22	14	16
POL Cost	23		9
Production Program Startup Cost		1	
	23 +	14 +	16

cation purposes only. However, one group of sub-equations will be presented here for informational purposes, and anyone who desires a more complete description of the model can refer to the Working Group Model itself.

One equation is the Packaging and Shipping Cost equation. This equation, which attempts to formulate the packaging and shipping portion of life cycle costs, looks like this (57:Atch 8):

CT = CTWE + CTES + CTPAGE + CTCAGE + CTSTE + CTTNA + CTR

The first thing to remember is that most models use symbols to represent common items (15:2). In this case all of the symbols have a distinct meaning:

CT - packaging and shipping cost

CTWE - cost of packaging and shipping new engines

CTES - cost of packaging and shipping new engine spare sections, assemblies, and parts

CTPAGE - cost of packaging and shipping peculiar AGE

CTCAGE - cost of packaging and shipping common AGE

CTSTE - cost of packaging and shipping special test equipment

CTTNA - cost of packaging and shipping training equipment

CTR - cost of packaging and shipping replacement engines and replacement spare parts

Each one of these cost items has a sub-equation which derives its value. As an example of one of these

sub-equations, the equation which derives the cost of packaging and shipping replacement engines and replacement spare parts, or CTR, will be considered:

$$CTR = \sum_{n=1}^{NKSS} \frac{(AEFH)\ (NNPE_n)\ (UF_n)}{MTBR_n} \quad 2\ (NRTS_n) + (CONDB_n)$$

$$(PCSS_n)\ (1-OSS_n) + (POSS_n)\ (OSS_n) \quad (1.35)\ (WSS_n)$$

Rather than tabularly list the meaning of each symbol, the equation with each symbol explained is shown in Figure 16. As can be seen in this figure, the replacement engines and replacement spare parts portion of the total packaging and shipping cost is a summation of individual cost units. This summation of individual cost units is the foundation upon which this particular model works (57:Atch 1-3).

FIGURE 16

WORKING GROUP MODEL SUB-EQUATION

COST OF PACKAGING & SHIPPING REPLACEMENT ENGINES & SPARES

NO. OF ENGINE SPARE ITEMS SHIPPED

ANNUAL ENGINE FLYING HOURS

NO. OF nth KIND OF ITEM PER ENGINE

RATIO OF OPERATING HOURS TO FLYING HOURS (USE FACTOR)

FRACTION OF ITEMS OF KIND n NOT REPAIRED THIS STATION

CONDEMNED ITEMS OF KIND n AT BASE LEVEL

$$CTR = \sum_{n=1}^{NKSS} \frac{(AEFH)\ (NNPE_n)\ (UF_n)}{MTBR_n} \left[2(NRTS_n) + (CONDB_n) \right]$$

GREEK LETTER SIGMA WHICH INDICATES SUMMATION OF ITEMS n = 1 THROUGH n = NKSS

MEAN TIME BETWEEN REMOVAL FOR ITEM n

AVERAGE UNIT PACKAGING AND SHIPPING COST FOR THE nth KIND OF ENGINE SPARE ITEM BETWEEN DEPOT AND CONUS SHIPPING LOCATION

FRACTION OF THE nth KIND OF ENGINE REPLACEMENT ITEM SHIPPED TO OVERSEAS LOCATION

WEIGHT OF THE nth ENGINE SPARE ITEM SHIPPED BETWEEN DEPOT AND OPERATING LOCATIONS

$$\left[(PCSS_n)\ (1-OSS_n) + (POSS_n)\ (OSS_n) \right] \quad (1.35)\ \ (WSS_n)$$

AVERAGE UNIT PACKAGING AND SHIPPING COST FOR THE nth KIND OF ENGINE SPARE ITEM BETWEEN DEPOT AND OVERSEAS OPERATING LOCATION

APPENDIX B

MISSION OF THE AIR FORCE AERO
PROPULSION LABORATORY

This appendix details the mission of the Air Force Aero Propulsion Laboratory (AFAPL). Figure 17 is an organizational chart which depicts where the AFAPL is located in the Air Force Systems Command (AFSC) hierarchy. AFAPL is part of the Air Force Wright Aeronautical Laboratories (AFWAL).

The mission of the Air Force Laboratories is to:

> a. Advance the military capability state-of-the-art through investigation and exploitation of the frontiers of new technology.
> b. Support systems development through technical consultation, problem resolution, and specific development efforts (high risk areas, assigned subsystems and Engineering Developments).
> c. Explore approaches and alternatives for correcting deficiencies and satisfying operational requirements on a timely basis [58:1].

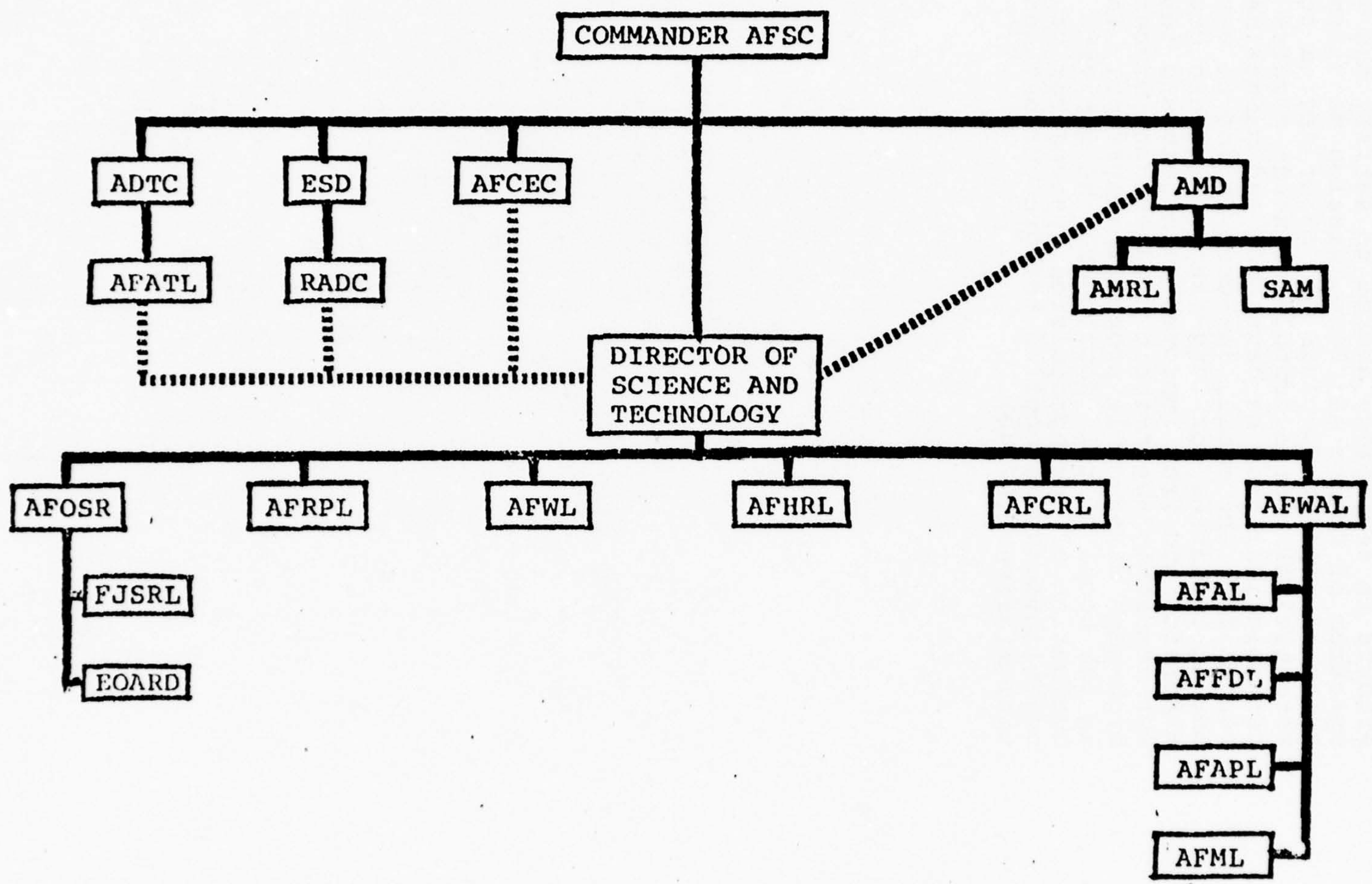
The AFAPL and three other Air Force Laboratories were consolidated under AFWAL in July 1975 as part of an AFSC reorganization. The mission of the AFWAL is to:

> . . . plan and execute USAF exploratory development advanced development, and selected research and engineering development programs for flight vehicles, aero-propulsion, avionics, and materials, and the USAF manufacturing methods program. It also provides support within its area of technical competence for the planning, development, and operation of aerospace systems, and to other Air Force, Department of Defense, and other Government agencies [58:8].

The AFAPL has four technical domains; each one is separately organized and each one has a different mission (58:40). The mission of the Turbine Engine Propulsion domain is:

Figure 17

AIR FORCE SYSTEMS COMMAND
ORGANIZATIONAL CHART (59:2)



Exploratory, advanced and prototype development efforts in technology needed to satisfy the wide spectrum of future Air Force mission requirements. Areas of emphasis include all major engine components. Potential Air Force propulsion needs require that a technological base be developed and maintained that ranges from the small, low-cost engine to very high thrust turbofans for long-range, subsonic cruise aircraft, and from improved turbojets and turbofans for transonic/super-sonic fighters and bombers to high-mach mixed-cycle propulsion systems. Included in the scope of this domain are the analysis and evaluation of turbopropulsion systems for other organizations, as applied to both current and potential missions [58:40].

APPENDIX C

WORK UNIT CODES

The WUC is the heart of the maintenance reporting system. Presented here is a listing of the systems which are represented by the first two digits of the five character WUC. This listing will enable the reader to identify the system which any given WUC comes from (46:21):

11	AIRFRAME
12	COCKPIT AND FUSELAGE COMPARTMENTS
13	LANDING GEAR
14	FLIGHT CONTROL
15	HELICOPTER ROTOR SYSTEM
16	ESCAPE CAPSULE
17	AERIAL RECOVERY SYSTEM
18	VERTICLE OR SHORT TAKEOFF AND LANDING (V/STOL) POWER AND CONTROL TRANSMISSION SYSTEM
21	RECIPROCATING POWER PLANT
22	TURBO PROP/TURBOSHAFT POWER PLANT
23	TURBO JET OR TURBO FAN POWER PLANT
24	AUXILIARY POWER PLANT
25	ROCKET POWER PLANT
26	HELICOPTER ROTARY WING DRIVE SYSTEM
31	ELECTRIC PROPELLER
32	HYDRAULIC PROPELLER
33	ELECTRO HYDRAULIC PROPELLER
34	MECHANICAL AND FIXED PITCH PROPELLERS

41 AIR CONDITIONING, PRESSURIZATION AND SURFACE ICE CONTROL

42 ELECTRICAL POWER SUPPLY

44 LIGHTING SYSTEM

45 HYDRAULIC AND PNEUMATIC POWER SUPPLY

46 FUEL SYSTEM

47 OXYGEN SYSTEM

49 MISCELLANEOUS UTILITIES

51 INSTRUMENTS

52 AUTOPILOT

53 DRONE AIRBORNE LAUNCH AND GUIDANCE SYSTEMS

54 TELEMETRY

55 MALFUNCTION ANALYSIS AND RECORDING EQUIPMENT

56 AUTOMATIC ALL WEATHER LANDING SYSTEM

57 INTEGRATED GUIDANCE AND FLIGHT CONTROL - Includes Auto Pilot When Part of Integrated System

61 HF COMMUNICATIONS

62 VHF COMMUNICATIONS

63 UHF COMMUNICATIONS

64 INTERPHONE

65 IFF

66 EMERGENCY COMMUNICATIONS

69 MISCELLANEOUS COMMUNICATIONS EQUIPMENT

71 RADIO NAVIGATION

72 RADAR NAVIGATION

73 BOMBING NAVIGATION

74	FIRE CONTROL
75	WEAPON DELIVERY
76	ELECTRONIC COUNTERMEASURE
77	PHOTOGRAPHIC/RECONNAISSANCE
81	AIRBORNE COMMAND AND CONTROL SURVEILLANCE RADAR (AWACS)
82	COMPUTER AND DATA DISPLAY (GRAPHIC)
89	AIRBORNE BATTLEFIELD COMMAND CONTROL CENTER (CAPSULE)
91	EMERGENCY EQUIPMENT
92	TOW TARGET EQUIPMENT
93	DRAG CHUTE EQUIPMENT
94	METEOROLOGICAL EQUIPMENT
95	SMOKE GENERATOR, SCORING AND TARGET AREA AUGMENTATION SYSTEMS, AND AIRBORNE CO-OPERATIONAL EQUIPMENT
96	PERSONNEL AND MISCELLANEOUS EQUIPMENT
97	EXPLOSIVE DEVICES AND COMPONENTS
98	ATMOSPHERIC RESEARCH EQUIPMENT

APPENDIX D

SAMPLE FROM TABLES OF ALLOWANCE
WHICH ARE USED IN ESTIMATING
AEROSPACE GROUND
EQUIPMENT COSTS

Figure 18

Table of Contents
TA-760 (41:3)

PART	SECT	SUB-SECT	END-ITEM	TITLE	CARD	FRAME
				PART		
	A			PART B - SECTION A SHOP TOOLS AND EQUIPMENT	1	E 1
B	B			PART B SEC B TEST STANDS AND AUXILIARY EQUIPM	1	J 1
C	A			PART C - SECTION A J33 SERIES ENGINES	1	E 2
C	C			PART C - SECTION C J-71-11 AND -13 ENGINES		N 2
C	E			PART C - SECTION E TF 41-A1 ENGINES	1	E 3
D	A			PART D - SECTION A J47 SERIES ENGINES		H 3
D	C			PART D SEC C J79 SERIES ENGINES		H 4
D	E			PART D SEC E T58 SERIES ENGINE ENGINE APPLICATION		6
D	F			PART D SEC F T64 SERIES ENGINE ENGINE APPLICATION		C 7

Figure 19

Organizational Item List
TA-760 (41:81)

PART D SEC C J79 SERIES ENGINES
ENGINE APPLICATION

COL A - J79-GE-38 COL C - J79-GE-15
COL B - J79-GE-7A COL D - J79-GE-17

STOCK NUMBER / NOMENCLATURE	BASIS OF ISSUE COL	COL
1730-00-203-8694	A B C D	
ADAPTER FORWARD FRAME LIFT HORIZ P/N 1C2538	A	B 1/160
1730-00-203-8700	A B C D	
ADAPTER LIFE-FRONT/REAR COMPR STATOR ASSY P/N 1C2429	A	B 1/72
1730-00-203-8701	A B C D	
ADAPTER - ENG LIFT FRONT FRAME P/N 1C2483	A	B 1/160
1730-00-203-8775	A B C D	
SLING COMPR ROTOR HORIZ LIFE 1C2583	A	B 1/160
1730-00-522-2760	A	
BAR LIFTING TURBINE CASTING P/N 1C2437	A	B 1/72
1730-00-522-2762	A B C D	
BAR LIFTING TURBINE ROTOR ASSY HORIZ P/N 1C2411	A	B 1/72

Figure 20

Master Equipment Management Index
TA-001 (47:318)

Basic 01 Dec 76

STOCK NUMBER	REFERENCE NOMENCLATURE	AAC	BUD CODE	CATL ACT	UNIT COST
1730-00-203-6485	JACK, DOLLY TYPE, HYDRAULIC	C	A	SE	407.00
1730-00-203-8694	*ADAPTER FORWARD FRAME LIFE HORIZ* P/N 1C2538	C	A	SE	44.29
ASC	333		760		
1730-00-203-8696	ADAPTER TURBINE ROTOR ASSY FORWARD E ND 1C2409	C	A	SE	48.00
1730-00-203-8697		C	A	SE	42.00
1730-00-203-8700	ADAPTER LIFE-FRONT/REAR COMPR STATOR ASSY P/N 1C2429	C	A	SE	90.13

APPENDIX E

SAMPLE IROS LOGISTICS SUPPORT COST OUTPUTS

This appendix contains the sample IROS logistics support cost outputs which are discussed in some detail in Chapter III. They are included here so that the reader who desires a fuller understanding of the material presented in Chapter III can readily refer to them.

Figure 21

Logistic Support Cost Ranking
Selected Items

8 01
WEAPON SYSTEM. A0070 OCALC LOGISTIC SUPPORT COST RANKING RCS LOG-MMO(Q)7213(1) K051.PN1L PAGE
AFM 65-110/66-1 DATA AS OF 76 JUN SELECTED ITEMS DATE PROCESSED

WUC	NOUN	PERCENT SYSTEM	CAT IND	CURRENT RANK	CURRENT QTR LSC	1ST RANK	1ST PREV QTR LSC	2ND RANK	2ND PREV QTR $ LSC	3RD RANK	3RD PREV QTR LSC	SPEC INV	SPEC GFAE
				FORCE LSC PER MONTH									
03100	PREFLIGHT INS	6.035	C	1	$153254	1	$171949	2	$135423	2	$141876		
03210	BASIC PO LAST	5.306	C	2	$134757	2	$159941	1	$142261	1	$147150		
73AJD	HARNESS INTR	4.219	B	3	$107141 P	323	$887	547	$378 P	258	$1097		
73DAO	RCVR XMTR	2.898	B P	4	$73605 P	8	$59747	3	$95307 P	19	$20750		
23100	TF41 ENGINE	2.491	C	5	$63254 P	12	$46276 P	6	$70158 P	10	$38286		
73AA0	ANTENNA-RECEI	2.463	B P	6	$62542	14	$44730 P	27	$13876 P	31	$14531		
73EA0	DIS UNIT HEAD	2.409	B P	7	$61178	6	$75038 P	5	$72051	4	$66152		

Figure 22

Logistic Support Cost Ranking
Work Unit Code Status

8 02
WEAPON SYSTEM A007D OCALC LOGISTIC SUPPORT COST RANKING RCS LOG-MMO(Q) 7213(2) K051.PN3L PAGE 29
AFM 65-110/66-1 DATA AS OF 76 JUN WORK UNIT CODE STATUS DATE PROCESSED 76 AUG 01

	FORCE LSC PER MONTH			
FORCE STATISTICS	CURRENT QTR	1ST PRCV QTR	2ND PREV QTR	3RD PREV QTR
LOGISTIC SUPPORT COST	$2,632,723	$2,834,626	$2,359,888	$2,343,200
TCTO MANHOURS COST	$93,131	$87,871	$86,611	$62,339
INVENTORY	388	339	338	383
FLYING HOURS	8,619	6,807	5,240	6,241
LANDINGS	4,985	4,028	3,214	3,647
23 ENGINE STATISTICS				
AIRCRAFT INVENTORY	388	339	338	383
OPERATING HOURS	8,619	6,807	5,240	6,241

TOTAL WUCS 3,679 TOTAL WUCS REPORTED THIS QUARTER 2,491

			FORCE LSC PER MONTH				
WUC	NOUN	PERCENT SYSTEM	CURRENT QTR LSC	1ST PREV QTR LSC	2ND PREV QTR LSC	3RD PREV QTR LSC	SPEC INV
03XXX		20.473	$519925	$535364	$441432	$475989	
04XXX		7.226	$183519	$201641	$204079	$247255	
11XXX	AIRFRAME	4.865	$123554	$110873	$120837	$142324	
12XXX	FUSELAGE COMP	1.142	$28997	$27804	$22728	$26733	
13XXX	LANDING GEAR	3.057	$77638	$79791	$76668	$83578	
14XXX	FLIGHT CONTRO	2.538	$64456	$78642	$75226	$75186	
23XXX	TURBOFAN PROP	6.790	$172446	$169456	$195071	$166684	

Figure 23

Logistic Support Cost Ranking
Work Unit Code Status

B 04
WEAPON SYSTEM A007D LOGISTIC SUPPORT COST RANKING RCS LOG-MMO(Q) 7213(2) K051.PN3L PAGE 24
AFM 65-110/66-1 DATA AS OF 76 JUN WORK UNIT CODE STATUS DATE PROCESSED 76 AUG 01

				---FORCE LSC PER MONTH---									
		PERCENT	CAT	CURRENT QTR		1ST PREV QTR		2ND PREV QTR		3RD PREV QTR		SPEC	SPECI
WUC	NOUN	SYSTEM	IND	RANK	LSC	RANK	LSC	RANK	LSC	RANK	LSC	INV	GFAE
231NM	FAIRING SUPP	0.008	C	838	$198	240	$1307	997	$127	287	$973		
231NN	CASE TURB EXH		B							2073	$15		
231PA	DUCT REAR BYP	0.007	C	922	$166	1135	$120	921	$160	752	$225		
231PB	RING SEAL MIX		B					2427	$1				
231PC	FAIR AS IN BY	0.005	B	1095	$118	1807	$33			2248	$9		
231PD	MIXER AS BYPA	0.027	B	363	$679	345	$807	556	$368	668	$279		
231PE	CONE AS IN TU	0.001	B	1710	$35	2376	$5	2122	$10	1959	$20		

Figure 24

Logistic Support Cost Ranking National
Stock Number Status

H 12
WEAPON SYSTEM A007D OCALC LOGISTIC SUPPORT COST RANKING RCS LOG-MMO(Q)72:13 (4) K051,PN6L PAGE 14
AFM 65-110/66-1 DATA AS OF 76 JUN NATIONAL STOCK NUMBER STATUS DATE PROCESSED 76 AUG 01

NSN	NSN NOUN	PRIME ALC	WUC	WUC NOUN	NSN LSC (BY WUC)	PERCENT SYSTEM	NUMBER TO SHOP	NSN RANK	TOTAL NSN LSC	TOTAL % SYSTEM
2995004169646	STARTER, ENGINE,	OC	23200	JET FUEL STARTE	$37270	3.634	6	6	$37270	3.634
3110001003556	CONE AND ROLLER	WR	13AC9	NOC	$51	0.005	0	511	$51	0.005
3110001599396	CONE AND ROLLER	WR	13AC9	NOC	$77	0.008	0	460	$77	0.008
3110001861119	CONE AND ROLLER	WR	13AF9	NOC	$30	0.003	0	590	$30	0.003
3110002750044	CONE AND ROLLER	WR	13AF9	NOC	$14	0.001	0	650	$14	0.001

Figure 25

Logistic Support Cost Maintenance
Action Summary

A 07
WEAPON SYSTEM A007D OCALC MAINTENANCE ACTION SUMMARY RCS LOG-MMO(Q)7215 K051.PN7L PAGE 164
AFM 65-110/66-1 DATA AS OF 76 JUN DATE PROCESSED 76 AUG 01

			ON EQUIPMENT								OFF EQUIPMENT								
			REPAIRED		EXPENDED		TO SHOP		NRTS		CONDEMNED		NO DEFECT		OTHER		ABORTS	
WUC	NSN	NOUN	UNIT	AV MH	UNIT	AV MH	UNIT	AV MH	UNIT	AV MH	UNIT	AV MH	UNIT	AV MH	UNIT	AV MH	BFA	IFA
23100	2915005314615CN	** NO BASELINE DATA, MASTER RECORD ESTABLISHED, M-H USED **																
		FAILURE	0	0.0	0	0.0	C	0.0	0	0.0	0	0.0			0	1.0	132	0
	999999999999999	TF41 ENGINE			0													
		FAILURE	3	6.4	0	0.0	41	10.7	22	0.9	0	0.0			5	0.0	999	999
		OTHER	480	10.4		0.0	2	6.0	4	1.3	C	0.0	29	0.0	2	0.0		
231A0	999999999999999	LP IP COMPRESSO																
		FAILURE	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0			0	0.0	568	0
		OTHER	5	1.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		
231AA	999999999999999	INLET ASSY ENGI																
		FAILURE	0	0.0	.0	0.0	0	0.0	0	0.0	0	0.0			1	4.0	999	999
		OTHER	6	0.8	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		

APPENDIX F

TURBOJET AND TURBOFAN APPLICATIONS

IN THE UNITED STATES AIR FORCE

The turbojet and turbofan engine types and applications for these types are provided in the following tables. Also included are the unit costs and the manufacturer of the engines. Although the exact date that these engines entered the active inventory is not provided it is interesting to note the general cost growth in engine unit price. For example, J-57P/F-19WA used on the B-52B aircraft has a standard unit cost of $269,970, while the F-101-GE-100 engine used on the B-1 aircraft, which will replace the B-52, has an estimated unit cost of $3,250,000.

Table 14

Turbojet Application
in the Air Force (56)

TYPE	AIRFRAME	UNIT COST	MANUFACTURER
J33A/35	T-33A	21,490	Allison
J47-GE25/25A	B-47 All Series KC-97L (POD	47,650	G.E.
J57P/F13/13A	RF-101C/H	154,832	P & W
J57P/F-19WA	B52-B/C/D/E	269,970	P & W
J57P/F21/21A/B	F-100C/D/F	185,772	P & W
J57P/F23/23A/B	TF/F-102A	165,738	P & W
J57F/P29/WA	B-52B/C/D/E	211,627	P & W
J57-P37/37A	RB57D	159,000	P & W
J57-P/F43/43W/ WA/WB	B52C/E/F/G/KC-135A-C/EC/KC/ NC-135A/H/K/N	228,511	P & W
J57-P/F55/A	F-101B/F, RF 101B, TF101F	149,892	P & W
J57-P/F/59W.	KC-135A/D/G/H/ KL/N/O/P/R/S	131,500	P & W
J60-P3/3A	NT/T-39A/B/D	63,011	P & W
J60-P5A	C140A	63,094	P & W
J65-W5F	RB/B-57 All Series	80,351	Wright
J69-T25/25A	T-37B/C/C123J	42,312	Continental
J71-A13	B/RB/WB-66B/C/D	225,000	Allison
J75-P17	F-106A/B	300,269	P & W
J75-P19	F105B	300,000	P & W
J75-P19W	F105D/F/G	221,843	P & W
J79-GE7/7A/B	F104C/D	277,197	G.E.
J79-GE11/11A/ 11A1/B	TF/RF/F104A/ B/G	167,000	G.E.
J79-GE15/A	F/RF-4C/D	155,300	G.E.
J79-GE17/A	F-4E/F/F-4G	163,505	G.E.
J85-GE5/F/G/H/ J/K	T-38A	78,500	G.E.
J85-GE13C/D	F-5A/B	120,000	G.E.
J85-GE17A	A-37B	109,000	G.E.
J85-GE21/A	F-5E/F	236,448	G.E.
YJ93-GE3	B70	1,250,000	G.E.

Table 15

Turbofan Application
in the Air Force (56)

TYPE	AIRFRAME	UNIT COST	MANUFACTURER
JT3D-3B (Commercial)	VC-137B/C	219,354	P & W
TF30-P1/1A	F-111A	705,364	P & W
TF30-P3	F-111A/E	789,000	P & W
TF30-P7	FB-111A	689,000	P & W
TF30-P9	F-111D	789,000	P & W
TF30-P100	F-111F	680,000	P & W
YTF33-P1	B-52H	218,529	P & W
TF33-P3	B-52H	188,725	P & W
TF33-P5	C/RC/VC/WC-135B/C/M/S/V	202,911	P & W
TF33-P7/7A	C-141A	266,292	P & W
TF33-P9	EC/RC-135C/J/U/V	208,300	P & W
TF33-P11A	RB-57F	220,035	P & W
TF33PW100A	E3A (AWACS)	930,000	P & W
TF34GE100	A-10	551,000E	G.E.
YTF39-GE1	C-5A	1,447,000	G.E.
TF39-GE1/1A	C-5A	888,000	G.E.
TF41-A1	A-7D	386,000	Allison
XF100-PW-100	F-15A	3,500,000E	P & W
YF100-PW-100	F-15A	1,500,000E	P & W
F100-PW-100	F-15A	1,620,000E	P & W
F101-GE-100	B-1	3,250,000E	G.E.

APPENDIX G

WORK PERFORMANCE CATEGORIES

This appendix contains the work performance categories used in depot maintenance. These categories are found in many data products which report on depot maintenance activities (specifically they are used in the HO36B data system). Included in this appendix are two sets of categories. The first set, titled Work Accomplished Codes, are valid for reports published prior to 21 October 1975. The second set, titled Work Performance Categories, replaced the Work Accomplished Codes when DOD 7220.29H was published In October 1975

Work Accomplished Codes (prior to 21 Oct 1975)

a. Code A - Overhaul. The disassembly, test, and inspection of the operating components and the basic structure to determine and accomplish the necessary rework, rebuild, replacement, and servicing required to obtain the desired performance. It is synonymous with the terms "Rework" or "Rebuild."

b. Code B - Progressive Maintenance. A predetermined amount of work that represents a partial overhaul under a program that permits the complete overhaul to be accomplished during two or more time periods. It is synonymous with the terms, "Airline Maintenance," "Cycle Maintenance," "Restricted Availability," "Preventive Servicing," or "Recondition."

c. Code C.- Coversion. The alteration of the basic characteristics of an item to such an extent as to change the mission, performance or capability.

d. Code D - Activation. The depreservation, servicing, inspection, test and replacement of assemblies or subassemblies as required to return an item from storage or inactive pool status to operational use.

e. Code E - Inactivation. The servicing and preservation of an item prior to entering storage or an inactive pool.

f. Code F - Renovation. The proof and test evaluation and rework of ammunition or ordinance items as required for retaining the desired capability.

g. Code G - Analytical Rework. The disassembly, test, and inspection of items to determine and accomplish the necessary rework, rebuild, replacement, or modification required. It includes the technical analysis of the findings and determination of maintenance criteria.

h. Code H - Modification. The alteration or change of the physical make-up of a weapon/support system, sub-system, component, or part in accordance with approved technical direction.

i. Code I - Repair. Action taken to restore to a serviceable condition an item rendered unserviceable by wear, failure, or damage.

j. Code J - Inspection and Test. The examination and testing required to determine the condition or proper functioning as related to the applicable specifications.

k, Code K - Manufacture. The fabrication of an item by application of labor and/or machines to material.

l. Code L - Reclamation. The authorized processing of items to obtain parts or components that are to be retained in the inventory prior to taking disposal action of the remaining items.

m. Code M - Technical Assistance. The use of qualified Depot Maintenance personnel to provide technical information, instructions, or guidance, or to perform specific work requiring special skills, for operational activities or other maintenance organizations.

n. Code N - (Not used)

o. Code O - (Not used)

p. Code P - Programming and Planning Support. Includes consolidated annual maintenance and long range workload scheduling and resource utilization; centralized maintenance programming and planning for support of the lower levels of maintenance; development of maintenance concepts and the maintenance portion of logistic plans dealing with future weapons and equipment; programming of maintenance requirements in support of future weapons and other military equipment. Excludes the headquarters of the services (see Section IV.B of this DoD Instruction).

q. Code Q - Maintenance Technical and Engineering Support. Includes regional maintenance representatives, field liaison, maintenance technicians, contract technical services, contract engineering services in direct support of maintenance, contract technicians and engineers in direct support of maintenance.

r. Code R - Technical and Engineering Data. Includes engineering drawings, wiring diagrams, technical orders, engineering technical standards, technical handbooks, technical bulletins, and similar publications.

s. Code S - Technical and Administrative Training. All training except on-the-job training.

t. Code T - Tools and Equipment Other Than Real Property. Includes small hand tools, test equipment, machine tools, support equipment, but excludes common use non-technical equipment, e.g., automotive vehicles.

u. Code U - Industrial Facilities. Includes construction, alterations and improvements of all maintenance technical buildings [59:38-39].

Work Performance Categories (after 21 Oct 1975)

a. Code A - Overhaul. The disassembly, test, and inspection of the operating components and the basic structure to determine and accomplish the necessary repair, rebuild, replacement and servicing required to obtain the desired performance. It is considered to be synonymous with the terms "rework" or "rebuild."

b. Code B - Progressive Maintenance. A predetermined amount of work that represents a partial overhaul under a program that permits the complete

overhaul to be accomplished during two or more time periods. It is considered synonymous with the terms "cycle maintenance," "restricted availability," "preventive servicing," or "recondition."

c. Code C - Conversion. The alteration of the basic characteristics of an item to such an extent as to change the mission, performance or capability.

d. Code D - Activation. The depreservation, servicing, inspection, test and replacement of assemblies or subassemblies as required to return an item from storage or inactive pool status to operational use.

e. Code E - Inactivation. The servicing and preservation of an item prior to entering storage or an inactive pool.

f. Code F - Renovation. The proof and test evaluation and rework of ammunition or ordnance items as required for retaining their desired capability

g. Code G - Analytical Rework. The disassembly, test and inspection of end-items, assemblies or subassemblies to determine and accomplish the necessary rework, rebuild, replacement, or modification required. It includes the technical analysis of the findings and determination of maintenance criteria. Includes prototype teardown, analysis and rework of an item to determine job and material specifications on a future workload.

h. Code H - Modification. The alteration or change of the physical makeup of a weapon/support system, subsystem, component, or part in accordance with approved technical direction.

i. Code I - Repair. Action taken to restore to a serviceable condition an item rendered unserviceable by wear, failure, or damage.

j. Code J - Inspection and Test. The examination and testing required to determine the condition or proper functioning as related to the applicable specifications.

k. Code K - Manufacture. The fabrication of an item by application of labor and/or machines to material.

l. Code L - Reclamation. The authorized processing of end-items, assemblies or subassemblies to obtain parts or components that are to be retained in the inventory prior to taking disposal action on the remaining items. Covers demilitarization actions on items prior to disposal when the demilitarization is incidental to the reclamation.

m. Code M - Storage. The inspection, represervation and maintenance in a storage status of weapons and equipment items as well as their subsystems and components in the supply system.

n. Code N - Technical Assistance. The use of qualified depot maintenance personnel to provide technical information, instructions, or guidance, or to perform specific work requiring special skills, for operational activities or other maintenance organizations. Includes all demilitarization other than that incidental to reclamation (Code L).

o. Code O - NOT USED.

p. Code P - Programming and Planning Support. Includes consolidated long-range workload scheduling and resource utilization; centralized maintenance programming and planning for support of all levels of maintenance; all logistics support exclusive of engineering effort in the programming and development of maintenance support requirements for weapon systems and weapons support activities.

q. Code Q - Maintenance Technical and Engineering Support. Includes the technical and engineering effort in development of maintainability concepts and the maintenance portion of logistics plans dealing with future and present weapons and equipment. Includes regional maintenance representatives, field liaison, maintenance technicians, contract technical services, contract engineering services in direct support of maintenance, contract technicians and engineers in direct support of maintenance.

r. Code R - Technical and Engineering Data. Includes the preparation of technical and engineeiing data as applied to all categories of equipment. Includes engineering drawings, wiring diagrams, technical orders, engineering technical orders, engineering technical standards, technical handbooks, technical bulletins and similar publications. Provides for the preparation, editorial review and/or

revision of equipment publications pertaining to the operation, repair and repair parts support of DoD materiel. Preparation includes, but is not limited to, the consolidation of source data, drawings and art work, editing, preparation of final printable copy and printing. Includes significant identifiable effort within organic maintenance or at other DoD specialized support functions to produce data in support of maintenance, such as cryptographic or test equipment support data.

s. Code S - Technical and Administrative Training. Includes educational units conducting maintenance training and training associated with new weapon systems or support systems which have been or will be introduced into the DoD inventory. At depot maintenance activities, only training associated with new equipment is maintenance support. This training is separately funded by specific funding documents. Other training accomplished at depot maintenance activities in support of the depot maintenance operation is not maintenance support, but a part of the depot maintenance operation.

t. Code T - Nonmaintenance Work. Used to assure completeness of maintenance work force reporting [59: E-1 - E-3].

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